Total Maximum Daily Load for Sediment/Siltation and Organic Enrichment/Low Dissolved Oxygen

Dump Lake

Yazoo County, Mississippi

[PROPOSED Report – June 23, 2003]

Prepared for:

Mississippi Department of Environmental Quality
Office of Pollution Control
TMDL/WLA Section/Water Quality Assessment Branch

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FOREWORD

This report has been prepared in accordance with the schedule contained within the federal consent decree dated December 22, 1998. The report contains one or more Total Maximum Daily Loads (TMDLs) for water body segments found on Mississippi's 1996 Section 303(d) List of Impaired Water Bodies. Because of the accelerated schedule required by the consent decree, many of these TMDLs have been prepared out of sequence with the State's rotating basin approach. The implementation of the TMDLs contained herein will be prioritized within Mississippi's rotating basin approach.

The amount and quality of the data on which this report is based are limited. As additional information becomes available, the TMDLs may be updated. Such additional information may include water quality and quantity data, changes in pollutant loadings, or changes in land use within the watershed. In some cases, additional water quality data may indicate that no impairment exists.

Prefixes for fractions and multiples of SI units

Fraction	Prefix	Symbol	Multiple	Prefix	Symbol
10^{-1}	deci	D	10	deka	da
10^{-2}	centi	C	10^{2}	hecto	h
10^{-3}	milli	M	10^{3}	kilo	k
10^{-6}	micro	µ	10^{6}	mega	M
10^{-9}	nano	N	10^{9}	giga	G
10^{-12}	pico	P	10^{12}	tera	T
10^{-15}	femto	F	10^{15}	peta	P
10^{-18}	atto	A	10^{18}	exa	E

Conversion Factors

To Convert From	To	Multiply by	To Convert From	To	Multiply by
Acres	Square miles	0.0015625	Days	Seconds	86400
Cubic feet	Cubic meter	0.028316847	Feet	Meters	0.3048
Cubic feet	Gallons	7.4805195	Gallons	Cubic feet	0.133680555
Cubic feet	Liters	28.316847	Hectares	Acres	2.4710538
Cubic feet per second	Gallon per minute	448.83117	Miles	Meters	1609.344
Cubic feet per second	Million gallon per day	0.6463168	Milligrams per liter	Parts per million	1
Cubic meters	Gallons	264.17205	Micrograms per liter times cubic feet per second	Grams per day	2.45

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Total Maximum Daily Load (TMDL) for Sediment / Siltation, Organic Enrichment/Low Dissolved Oxygen, and Nutrients in Dump Lake MS370DLM, Yazoo County, Mississippi

TMDL AT A GLANCE

State:	Mississippi
County:	Yazoo County
303(d) Listed Water Body:	Yes
Year Listed:	1996
303 (d) List Segment ID:	MS370DLM
HUC:	08030207 – Lower Yazoo
Constituents Causing Impairment:	Sediment, Nutrients and Organic Enrichment/Low DO
Source of Pollutants:	Agriculture, Aquaculture, and Natural Background
Data Source:	None available
Designated Uses:	Aquatic life support
Applicable Water Quality Standard:	*Sediment*: Narrative water quality criteria *Organic Enrichment/Low DO:* General water quality criteria for dissolved oxygen: a daily average of 5.0 mg/L.
Water Quality Target:	*Sedimentation/Siltation*: Average Annual sediment sedimentation rate of 0.58 cm/year to 0.34 cm/year *Organic Enrichment/Low DO:* Daily Average DO of 5.0 mg/L
Technical Approach:	*Sedimentation/Siltation:* GWLF watershed model *Organic Enrichment/Low DO:* CE-QUAL-W2 receiving water model
TMDL:	*Sedimentation/Siltation: 0.75 – 0.44 tons/acre/year* *Organic Enrichment/Low DO:* 234 lbs/day of TBODu
WLA:	*Sedimentation/Siltation: 0.75 – 0.44 tons/acre/year* *Organic Enrichment/Low DO:* 0 lbs/day of TBODu
LA:	*Sedimentation/Siltation: 0.75 – 0.44 tons/acre/year* *Organic Enrichment/Low DO:* 234 lbs/day of TBODu
Margin of Safety:	Implicit

Executive Summary

Dump Lake, located in Yazoo County, Mississippi, is an oxbow lake formed by an abandoned meander of the Yazoo River. Mississippi Department of Environmental Quality (MDEQ) has identified Dump Lake as not meeting its designated use of Aquatic Life Support. Water bodies not meeting their designated use are listed as impaired as required by Section 303(d) of the Clean Water Act and the U.S. Environmental Protection Agency's (EPA) Water Quality Planning and Management Regulations (40 CFR part 130). The lake (water body MS370DLM) is on the Mississippi Section 303(d) list as impaired due to sediment/siltation, nutrients, and organic enrichment/low dissolved oxygen (DO). Mississippi currently does not have standards for allowable nutrient concentrations, so a Total Maximum Daily Load (TMDL) specifically for nutrients will not be developed. However, because elevated levels of nutrients may cause low levels of DO, the TMDL developed for organic enrichment/low DO also addresses the potential impact of elevated nutrients in the water body.

Section 303(d) requires the development of TMDLs for those water bodies on the impaired waters list. A TMDL is the sum of the allowable amount of a single pollutant that a water body can receive from all contributing point and nonpoint sources and still meet water quality standards. The process is designed to restore and maintain the quality of those impaired water bodies through the establishment of pollutant specific allowable loads. The water quality standard for sedimentation/siltation is narrative. The water quality standard for DO is a daily average of 5.0 mg/L with an instantaneous minimum of not less than 4.0 mg/L.

To evaluate the relationship between the sources, their loading characteristics, and the resulting conditions in the lake, a combination of analytical tools was used. Assessments of the nonpoint source loading into the lake were developed for the Dump Lake watershed using the Generalized Watershed Loading Function (GWLF) computer program. GWLF provided estimates of nutrients and sediments transported to the lake for individual land use categories. The lake was evaluated using the CE-QUAL-W2 water quality simulation computer model to estimate the concentrations of DO and oxygen-consuming constituents. The lake was divided into 10 segments to represent the system. The results of the watershed and lake models were compared with observed water quality data to evaluate the models' performances.

Model results were evaluated for the period from 1997 to 2000, which presented a range of climatic conditions. The year 1997, which was a predominantly wet year, was identified to be the critical period for the TMDL, i.e., reflective of the poorest water quality conditions in the lake. Model segment 6 was chosen as the location for evaluating the TMDL. This location exhibited the poorest water quality conditions in the lake based on model results.

For this TMDL, the loadings of oxygen demanding material are given in terms of total ultimate biochemical oxygen demand (TBODu). TBODu represents the oxygen consumed by microorganisms while stabilizing or degrading carbonaceous or nitrogenous compounds under aerobic conditions. A 45 percent reduction of the oxygen demanding source loadings or TBODu coming from the watershed is recommended to meet the prescribed DO criteria of a daily average of 5 mg/L. The target selected for sedimentation/siltation was selected as a range of values, from 0.58 cm/year to 0.34 cm/year. It should be noted, however, that the reductions specified in this TMDL report represent just one example of how pollutant loadings could be modified in order to improve water quality in Dump Lake. Watershed management scenarios other than those included in this report are possible. There is little hydrological and water quality data available for Dump Lake, and the management scenarios could be modified based on a reevaluation of the data and modeling if these data become available. For the present time, it is anticipated that some reductions of the current load can be achieved through a combination of land use and restoration practices such as erosion and sediment control practices, reduced tillage practices on croplands, forest management, and stream restoration.

According to 40 CFR Section 30.2 (i), TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measure. In this case, the measure used is in ton/acre/year, i.e., the tons of sediment that can be discharged from an acre of a subwatershed per year and still attain the applicable water quality standard. This results in a range of acceptable reference yields of 0.75 to 0.44 ton/acre/year. For this TMDL, it is appropriate to apply the same target yield to permitted and unpermitted watershed areas. For load TMDLs the permitted and unpermitted are summed to calculate the TMDL. Because this TMDL is expressed as a yield, as long as all activities, permitted or unpermitted, meet the same yield, the TMDL will be met, regardless of the relative load contribution.

Wet weather sources of sediment, which are discharged to a receiving water body as a result of the storm events, are considered to be the primary concern for this sediment TMDL. These wet weather sources can be broadly defined, for the purposes of this TMDL, into two categories: wet weather sources regulated by the National Pollutant Discharge Elimination System (NPDES) program, and wet weather sources *not* regulated by NPDES. Wet weather sources regulated by the NPDES program include industrial activities, certain construction activities, and discharges from Municipal Separate Storm Sewer Systems (MS4s). The wet weather NPDES-regulated sources are provided a waste load allocation (WLA) in this TMDL, and all other wet weather sources of sediment (those not regulated by NPDES) are provided a load allocation (LA).

There are no municipal, industrial, or commercial facilities in the Dump Lake Watershed with NPDES permits that are permitted for Total Suspended Solids (TSS). If present, it would not be appropriate to include these facilities since these sources provide negligible loadings of sediment to the receiving waters compared to wet weather sources (for example, NPDES-regulated construction activities, MS4s, and nonpoint sources). Also, the TSS component of a NPDES permitted facility is different from the pollutant addressed within this TMDL because the TSS component of the permitted discharges is generally composed more of organic material, and therefore, provides less direct impact on the biologic integrity of a stream (through settling and accumulation) than would stream sedimentation due to soil erosion during wet weather events. The pollutant of concern for the sedimentation TMDL is sediment from land use runoff.

Any future WLAs provided to municipal and industrial NPDES-permitted dischargers will be implemented through the state's NPDES permit program and are not included in this TMDL. The wet weather WLAs provided to the NPDES-regulated construction activities and MS4s will be implemented through best management practices (BMPs) as specified in Mississippi's General Stormwater Permits for Small Construction, Construction, and Phase I & II MS4 permits, which can be found on the MDEQ Web site (www.deq.state.ms.us). It is not technically feasible to incorporate numeric sediment limits into permits for these activities/facilities at this time. LAs for non-point sources will be achieved through the voluntary application of BMPs. Properly designed and well-maintained BMPs are expected to provide attainment of the wet weather WLAs and LAs.

The TMDLs are presented in Tables ES-1, ES-2 and ES-3. The margin of safety (MOS) has been addressed through implicit assumptions.

Table ES-1. TMDL for TBODu for Dump Lake

Pollutant	WLA (lb/day)	LA (lb/day)	MOS	TMDL (lb/day)
CBODu	0	154	Implicit	154
NBODu	0	80	Implicit	80
TBODu	0	234	Implicit	234

Table ES-2. TMDL for Sedimentation rate of 0.58 cm/year for Dump Lake

Pollutant	WLA (ton/acre/year)	LA (ton/acre/year)	MOS	TMDL (ton/acre/year)
Sediment	0.75	0.75	Implicit	0.75

Table ES-3. TMDL for Sedimentation rate of 0.34 cm/year for Dump Lake

Pollutant	WLA (ton/acre/year)	LA (ton/acre/year)	MOS	TMDL (ton/acre/year)
Sediment	0.44	0.44	Implicit	0.44

1.0 Problem Understanding

The identification of water bodies not meeting their designated use and the development of total maximum daily loads (TMDLs) for those water bodies are required by Section 303(d) of the Clean Water Act and the U.S. Environmental Protection Agency's (EPA) Water Quality Planning and Management Regulations (40 CFR part 130). A TMDL is the sum of the allowable amount of a single pollutant that a water body can receive from all contributing point and nonpoint sources and still meet water quality standards. The process is designed to restore and maintain the quality of those impaired water bodies through the establishment of pollutant-specific allowable loads.

The Water Quality Assessment Branch of the Mississippi Department of Environmental Quality (MDEQ) has identified Dump Lake (Photo 1) as being impaired as reported in the Mississippi 1998 Section 303(d) List of Water Bodies. The lake (water body MS370DLM) is listed as impaired due to sediment/siltation, nutrients, and organic enrichment/low dissolved oxygen (DO). This report presents the approach taken to develop TMDLs for Dump Lake as well as review of the potential causes of impairment and the required TMDL components.

Photo 1. Dump Lake

1.1 Lake Description

Oxbow lakes are formed by a long erosional process within a meandering stream. Meandering streams have a sinuous channel with broadly looping curves and exhibit an unequal distribution of flow velocity. As a consequence of the unequal velocities, the outer bank is eroded and sediment deposition occurs along the opposite side of the channel. The net effect is that the meander migrates laterally. Over time the channel becomes so sinuous that the land separating the adjacent meanders becomes very narrow.

During a flood, the stream will abandon its channel, cutting through the narrow strip of land, and flow the shorter distance (Monroe and Wicander, 1992). Sediment transported by the stream is deposited along the new stream bank at the site of the abandoned meander. Once the abandoned meander is completely isolated from the main channel it becomes an oxbow lake. Figure 1-1 below demonstrates this process. Over time, oxbow lakes naturally fill with sediment.

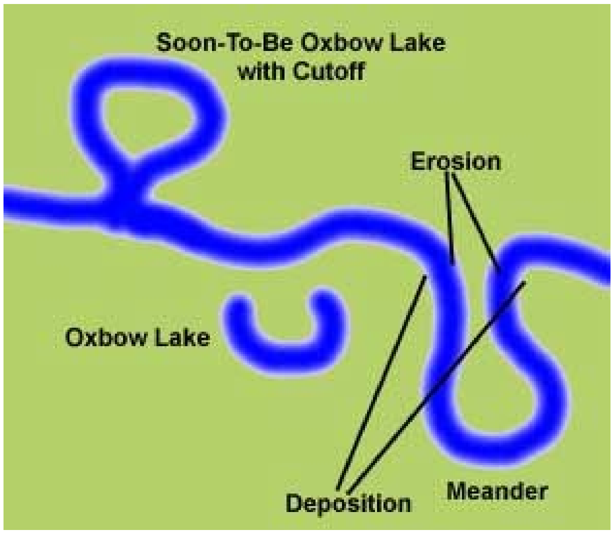

Figure 1-1. Oxbow Lake Creation Process

Dump Lake, with a surface area of 415 acres, is an oxbow lake that was formed on an abandoned arm of the Yazoo River. The lake's aquatic habitat is degraded by sedimentation as a result of agricultural runoff as well as runoff from the nearby hills. The sediment load carried by one of the streams draining into the lake has formed a large silt bar that has traversed two-thirds the way across the lake, requiring a pilot channel to be constructed to allow flow into the lake. Morphometric and hydraulic data for Dump Lake are shown in Table 1-1.

Table 1-1. Morphometric and Hydraulic Characteristics of Dump Lake

Parameter	**Measured**
Surface area (ac)	415 (0.65 mi^2)
Drainage area (ac)	14,556 (22.7 mi^2)
Depth	
Mean Lake (m)	2 (6.5 ft)
Maximum Lake (m)	3 (9.8 ft)

Source: Calculated from topographic data

1.2 Section 303 (d) Listed Water Bodies

Dump Lake (MS370DLM) is listed on the state's 303(d) list of impaired water bodies (Table 1-2).

Table 1-2. Section 303(d) Listing

Water Body Name	Water Body ID	Location	Beneficial Use	Impairment
Dump Lake	MS370DLM	Near Satartia	Aquatic Life Support	Sediment/Siltation, Organic Enrichment/Low DO and Nutrients

Excessive sedimentation from anthropogenic sources is a common problem that can affect water bodies in a number of ways. In the Mississippi Valley, suspended sediment and turbid conditions, caused by suspended sediment, are the primary water quality concerns (MDEQ, 1999). Suspended sediment can effect lake and stream biota in a number of ways. Deposited sediments reduce habitat complexity by filling in pools, riffle areas, and the interstitial spaces used by aquatic invertebrates. Elevated turbidity reduces light penetration necessary for photosynthesis in aquatic plants, reduces feeding efficiency of visual predators and filter feeders, and lowers the respiration capacity in aquatic invertebrates by clogging gill surfaces. In addition, other contaminants such as nutrients and pesticides can be transported to lakes and streams during runoff events while attached to sediment particles.

DO has historically been used as the constituent that measures or indicates the overall quality of surface water. DO analysis measures the amount of gaseous oxygen dissolved in an aqueous solution, which enters the water by diffusion from the surrounding air, by aeration (rapid movement), and as a waste product of photosynthesis. Adequate DO is necessary for good water quality and is a necessary element to all forms of life. Decreases in the DO concentrations can cause changes in the types and numbers of aquatic macroinvertebrates that live in a water ecosystem. As the DO levels decrease, pollution-intolerant organisms are replaced by the pollution-tolerant worms and fly larvae and there is a decrease in species that cannot tolerate decreases in DO (Ricklefs, 1990).

Oxygen is used by plants and animals for respiration. Aerobic bacteria consume oxygen during the process of decomposition. When organic matter and nutrients such as animal waste, fertilizer, or improperly treated wastewater enter a body of water it is used by the bacteria within the streambed and the algae in the water column (Ricklefs, 1990, Wetzel, 1983). Algae and bacteria use the organic matter and nutrients for growth. The DO concentration decreases as the plant material dies off and is decomposed through the action of the aerobic bacteria.

Nitrogen transport is governed by several chemical, physical, and biological processes known as the nitrogen cycle. The nitrogen cycle consists of four processes (nitrogen fixation, ammonification, nitrification, and denitrification) that convert nitrogen gas into usable nitrogen forms and back into nitrogen gas. Nitrogen fixation converts gaseous nitrogen into ammonia while ammonification involves the breakdown of wastes and nonliving organic tissue into ammonia. The nitrification process oxidizes ammonia that results in nitrate and nitrite. Finally, nitrates are converted back into gaseous nitrogen through the denitrification process. Ammonia ions, nitrites, and nitrates are most important for water quality assessments because of their impact on water quality. The conversion of ammonia to nitrate consumes 4.57 pounds of oxygen for every pound of ammonia (USEPA, 1993).

Instream DO concentrations fluctuate daily. The diurnal variations in DO concentrations are mainly due to photosynthesis and respiration of aquatic plants such as phytoplankton, aquatic weeds, or algae (Chapra, 1997, Wetzel, 1983). Photosynthesis is the process by which plants use solar energy to convert simple inorganic nutrients into more complex organic molecules. Because of the need for solar energy, photosynthesis only occurs during daylight hours and is represented by the following simplified equation:

$$\underset{\text{(Carbon Dioxide)}}{6CO_2} + \underset{\text{(Water)}}{6H_2O} \text{ <---------> } \underset{\text{(Sugar)}}{C_6H_{12}O_6} + \underset{\text{(Oxygen)}}{6O_2}$$

In this reaction, photosynthesis is the conversion of carbon dioxide and water into sugar and oxygen so that there is a net gain of DO in the water body (Ricklefs, 1983). Conversely, respiration and decomposition operate the process in reverse and convert sugar and oxygen into carbon dioxide and water resulting in a net loss of DO to the water body. Respiration and decomposition occur at all times and are not dependent on solar energy. Water bodies exhibiting the typical diurnal variation of DO experience the daily maximum in mid-afternoon during which photosynthesis is the dominant mechanism, and the daily minimum in the predawn hours during which respiration and decomposition have the greatest effect on DO, and photosynthesis is not occurring (Wetzel, 1983).

1.3 Water Quality Standards and Beneficial Uses

The beneficial uses identified for Dump Lake are designated as aquatic life support (MDEQ, 2002). Although there are no specific applicable criteria for these beneficial uses, the criteria listed in Table 1-3 apply to all surface waters in Mississippi. The water quality objectives provide both a narrative and numeric basis for identifying appropriate TMDL endpoints for sedimentation/siltation and organic enrichment/low DO.

Table 1-3. Relevant Water Quality Objectives

Section	Water Quality Objective
Section II.3	Waters shall be free from materials attributed to municipal, industrial, agricultural or other discharges producing color, odor, taste, total suspended or dissolved solids, sediment, turbidity, or other conditions in such degree as to create a nuisance, render the waters injurious to public health, recreation or to aquatic life and wildlife or adversely affect the palatability of fish, aesthetic quality, or impair the waters for any designated use.
Section II.7	DO concentration shall be maintained at a daily average of not less than 5.0 mg/L with an instantaneous minimum of not less than 4.0 mg/L. When possible, samples should be taken from ambient sites according to the following guidelines: • For waters that are not thermally stratified, such as unstratified lakes, lakes during spring turnover, streams, and rivers. At mid depth if the total water column is 10 feet or less and at 5 feet from the water surface if the total water column is greater than ten feet. • For waters that are thermally stratified such as lakes, estuaries, and impounded streams. At mid depth if the epilimnion is 10 feet or less and at 5 feet from the water surface if the epilimnion depth is greater than ten feet.

Source: MDEQ, 2002.

1.4 Watershed Description

The Dump Lake watershed, which is part of the U.s. Geological Survey (USGS) hydrologic Unit Code (HUC) 08030207, encompasses approximately 22.7 square miles (14,556 acres). It is located in Yazoo County just southwest of Yazoo City, Mississippi (Figure 1-2). The watershed is located in a flat expanse of flood plain adjacent to the Yazoo River. The Dump Lake watershed has two distinct topographical sections. The northwestern portion of the watershed is flat and is part of the Mississippi River flood plain. The crops within this portion of the watershed are corn, cotton, rice, sunflowers, sorghum, soybeans, other small grains, winter wheat, and snap beans. It includes a very small percentage of manmade aquaculture ponds that are used for raising catfish. In contrast, the southeastern portion of the watershed is not part of the flood plain, has more changes in elevation, and is predominately forested.

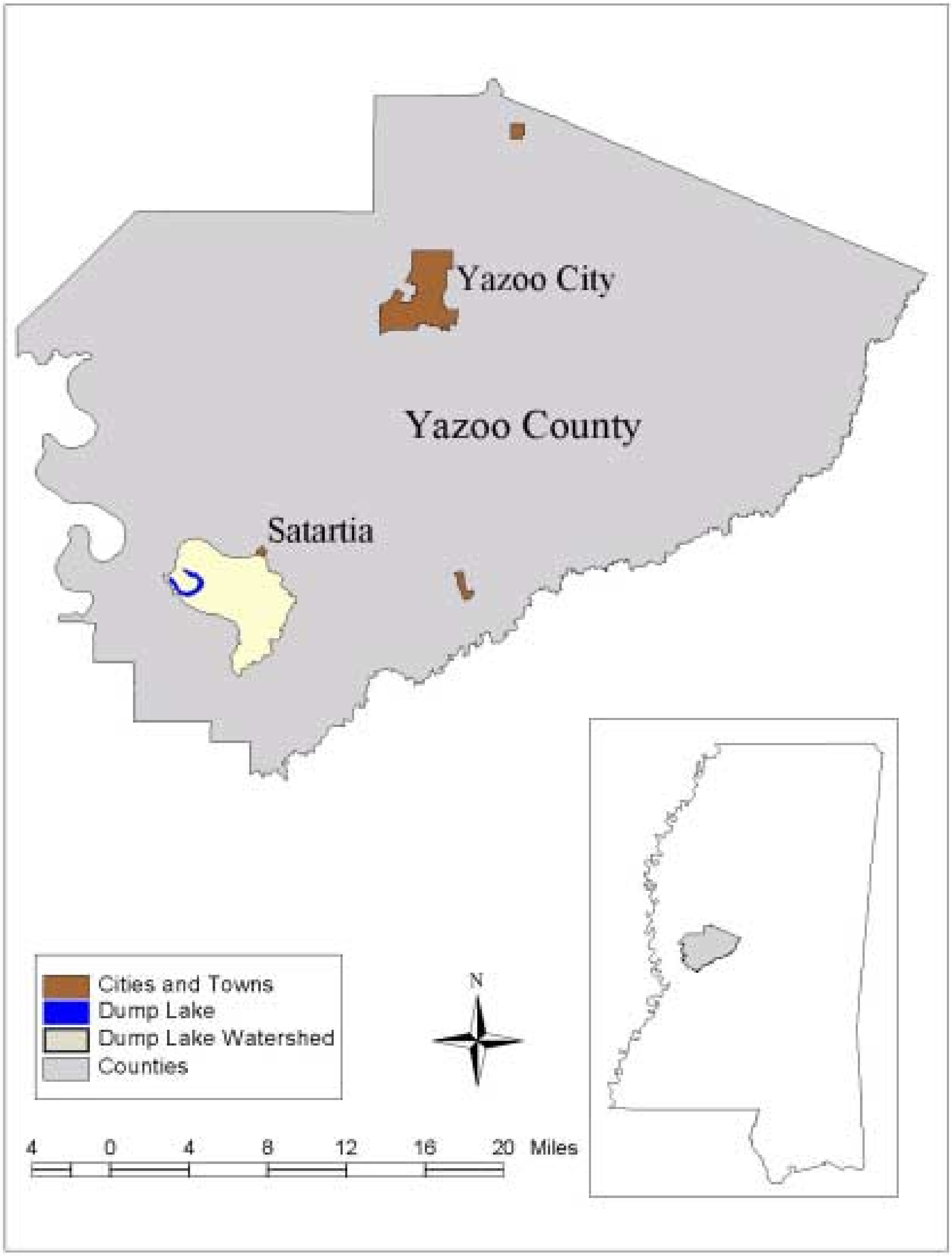

Figure 1-2. Watershed Location

1.4.1 Topography

The Dump Lake watershed has two distinct topographical sections (Figure 1-3). The northwestern portion of the watershed is flat and is part of the Mississippi River flood plain, with only about 45 feet of elevation change. In contrast, the southeastern portion of the watershed is not part of the flood plain and has more changes in elevation (about 225 feet). Streams draining into the flood plain created the topographic relief of this section of the watershed. Dump Lake is the lowest point, about 90 feet above mean sea level (MSL), in the watershed, and the southern tip of the watershed contains the highest point, about 360 feet above MSL.

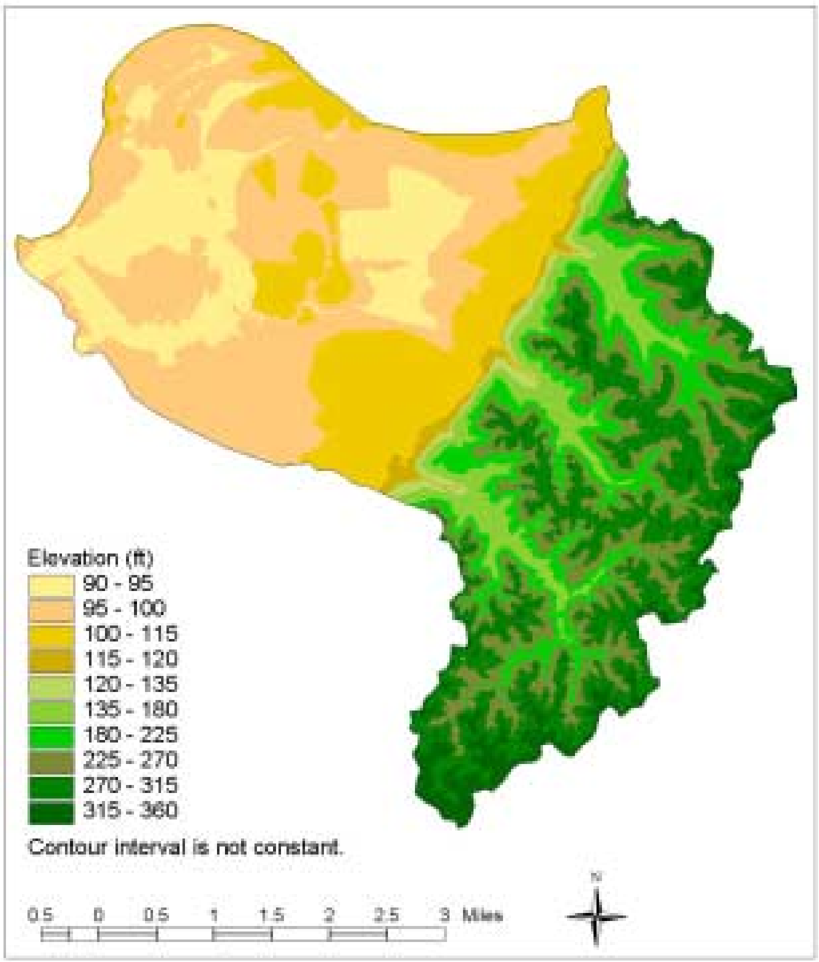

Figure 1-3. Digital Elevation Map

1.4.2 Soil Type

The watershed is characterized by Southern Mississippi Valley alluvium and Southern Mississippi Valley silty uplands. The watershed contains four soil types. These types are presented in Figure 1-4 and Table 3-1. The Memphis-Natchez-Collins soil group (MS040) is the major soil group of the upland region. The lowland region is comprised of the Sharkey-Forestdale-Dundee (MS017), Dundee-Dubbs-Sharkey (MS018), and Morganfield-Adler-Convert (MS037) soil groups. In the lowland areas the infiltration rates for these types of soil groups are characterized by slow to extremely slow permeability, and a soil erodibility factor (K) of 0.34 to 0.42. The upland area is comprised of the Memphis-Natchez-Collins (MS040) soil group. These soils are characterized by moderate permeability and a K of 0.49.

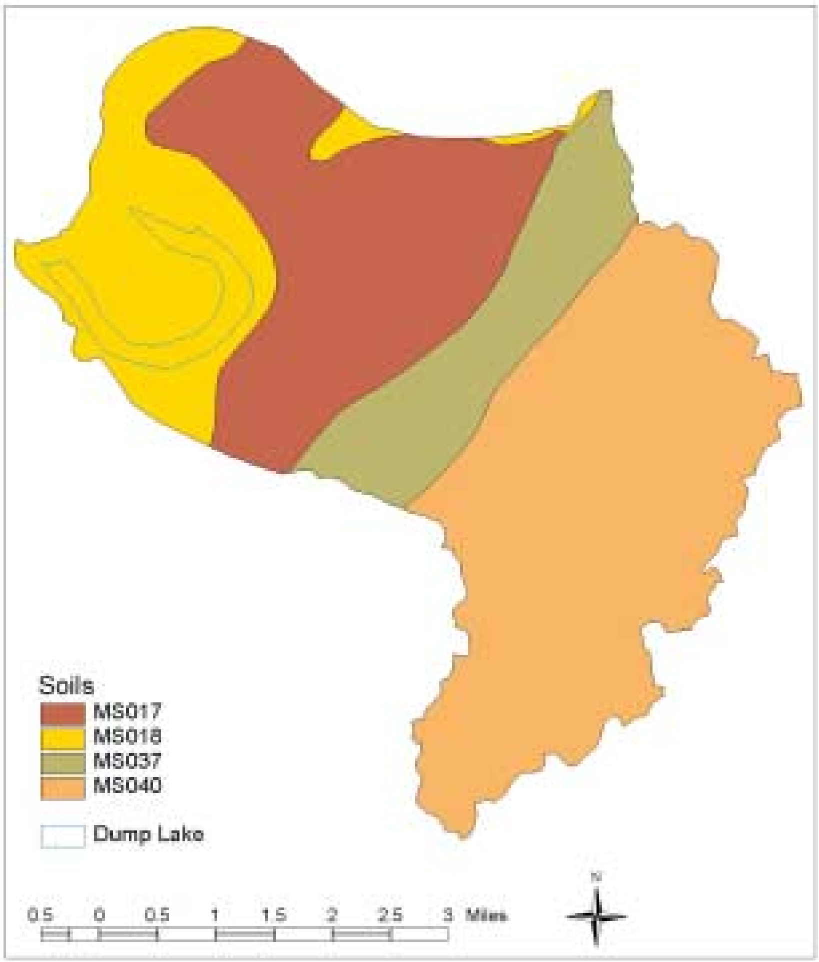

Figure 1-4. Soil Type

Table 1-4. Soil Types

Soil Type	Soil Name	Area (acres)
MS017	Dundee-Dubbs-Sharkey	3,953
MS018	Sharkey-Forestdale-Dundee	2,691
MS037	Morganfield-Adler-Convert	1,888
MS040	Memphis-Natchez-Collins	6,025
Total		14,556

1.4.3 Land Use

The majority of the watershed is rural with only less than one percent being residential. The majority (27 percent) of the watershed is cropland (cultivated agriculture). About 17 percent is pasture/range/non-agriculture, and about 56 percent is bottomland hardwood forests/shrubs/woods/swamp (other). Aquaculture accounts for approximately 0.26 percent of the watershed. Figure 1-5 and Table 1-5 present the land use areas in the watershed.

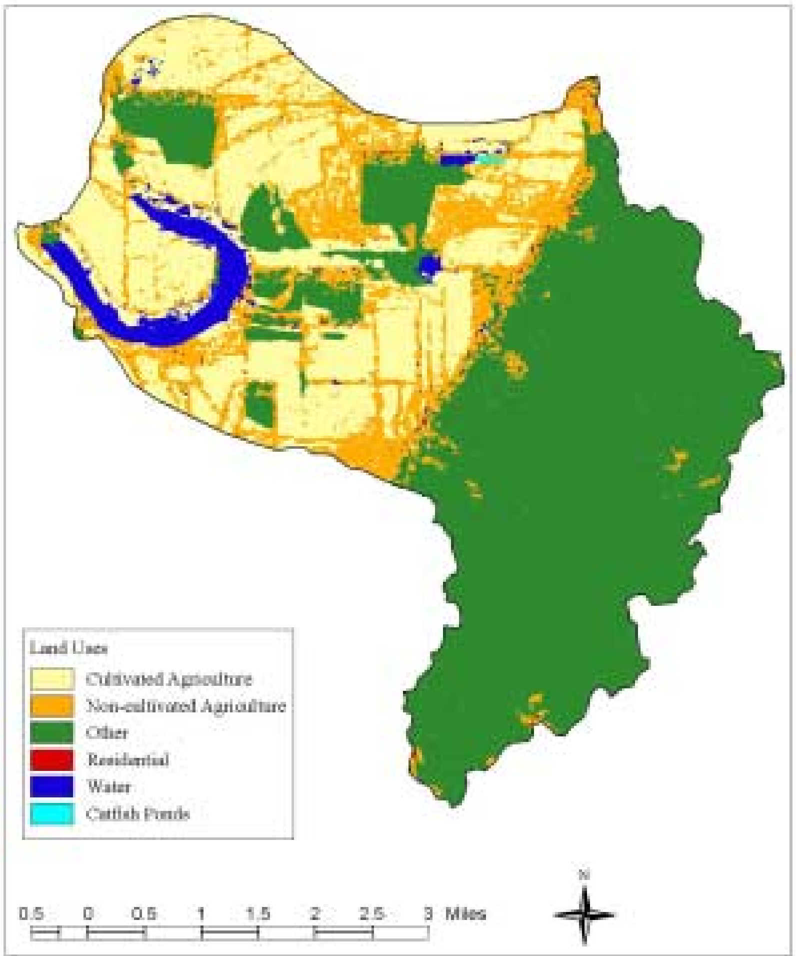

Figure 1-5. Mississippi Automated Resource Information System Land use

Table 1-5. Land Use

Land Use	Area (acres)	Area (%)
Cultivated agriculture	3,952	27
Non-cultivated agriculture	2,410	17
Other	8,115	56
Residential	42	<1
Catfish ponds	38	<1
Total	14,556	100

1.5 Climate Characteristics

Mississippi is located in the humid subtropical climate region, characterized by temperate winters and long, hot summers. Rainfall occurs more often in the winter and early spring. Late summer and fall are typically the driest times of the year. The state, however, is subject to periods of both drought and flood. Prevailing southerly winds provide moisture for high humidity from May through September. The potential for locally violent and destructive thunderstorms averages about 60 days each year. Eight hurricanes have struck Mississippi's coast since 1895, and tornadoes are a particular danger, especially during the spring season (MS State Climatologist, 2003).

Normal mean annual temperatures for the Jackson weather station, which is the closest weather station monitoring daily temperature, is 18 degrees Celcius. Low temperatures have dropped to 4 ^{o}C, while the maximum temperatures have reached 29 ^{o}C. Mississippi, in general, has a climate characterized by absence of severe cold in winter and the presence of extreme heat in summer. The ground rarely freezes and outdoor activities are generally planned year-round. Cold spells are usually of short duration, and the growing season is long (MS State Climatologist, 2003).

1.6 Socioeconomic Characteristics

The social and economic region for Dump Lake consists of Yazoo County, Mississippi. The county is a generally rural area covering 919 square miles, with only 31 persons per square mile (US DOC, Census, 2002). Comparatively, Mississippi has 61 persons per square mile and the United States has 80 persons per square mile.

The largest employment sectors in the county are services, government, manufacturing, retail trade, and farming. Most of the farming in the region consists of row crops including cotton, corn, soybeans, rice, and sorghum. Yazoo County ranked second in corn production in the state, third in sorghum production, fifth in cotton production, and tenth in soybean production (ClarionLedger.com, 1999). Catfish farming is also a growing industry in the Mississippi Delta area (Evans).

Dump Lake attracts recreational fishermen, contributing to the services sector of the regional economy. Recreational visitors benefit the local economy through expenditures on food, lodging, and sporting goods.

2.0 Data Summary

This section provides an inventory, description, and review of the data compiled to support TMDL development, as well as a brief description of data limitations.

2.1 Data Inventory

Tables 2-1 and 2-2 identify available data used to support the TMDL development effort. The two tables represent the major categories of data: geographic or location information, and monitoring data. Data include water quality observations, sediment source information, land use, and meteorological data.

Table 2-1. Available Geographic or Location Information

Type of Information	Data Source(s)[a]
Stream network	USEPA BASINS (Reach File, Versions 1 and 3), USGS NHD reach file, MARIS
Land use	MARIS
Cities/populated places	BASINS, MARIS, U.S. Census
Counties	BASINS, MARIS
Soils	BASINS (USDA-NRCS STATSGO), MARIS
Watershed boundaries	BASINS (8-digit hydrologic cataloging units), MARIS
Topographic and digital elevation models	BASINS (DEM), USGS digital raster graphs
Aerial photos	MARIS
Roads	BASINS, MARIS
Ecoregions	BASINS (USDA Level 3 ecoregions)
Water quality station locations	BASINS, MDEQ Clean Lakes Studies (FTN Associates, 1991)
Meteorological station locations	BASINS, NOAA-NCDC
Stream gage stations	BASINS, USGS
Surface geology	MARIS
Dam locations	MARIS
Impaired water bodies (303(d)-listed segments)	MDEQ

[a] USEPA = U.S. Environmental Protection Agency, BASINS = Better Assessment Science Integrating Point and Nonpoint Sources, USGS = U.S. Geological Survey, NHD = National Hydrography Dataset, MARIS = Mississippi Automated Resource Information System, MDEQ = Mississippi Department of Environmental Quality, USDA-NRCS = U.S. Department of Agriculture, Natural Resources Conservation Service, NOAA-NCDC = National Oceanic and Atmospheric Administration, National Climatic Data Center.

Table 2-2. Available monitoring data

Type of Information	Data Source(s)
Water Body Characteristics	
Physical data	BASINS (Reach File, Versions 1 and 3), USGS NHD reach data, MDEQ Clean Lakes Studies (FTN Associates, 1991)
Flow	
Historical flow record	USGS (gage sites located near but not in watersheds) MDEQ Clean Lakes Studies (FTN Associates, 1991)
Meteorological Data	
Rainfall	NOAA-NCDC, Earth Info
Temperature	NOAA-NCDC, Earth Info
Water Quality Data (surface water, groundwater)	
Water quality monitoring data	MDEQ Clean Lakes Studies (FTN Associates, 1991)

2.2 Monitoring Data Assessment of Dump Lake

There were limited data available for Dump Lake. Pesticide, heavy metals in sediment, and one storm event data were collected in early 2003. Table 2-3 below lists the provisional data collected by the Vicksburg District Corps of Engineers in February 2003 during a storm event.

Table 2-3. Data Collected Following Storm Event in Dump Lake.

Sample Location	Units	Total Suspended Solids	Total Dissolved Solids	Total Solids	Total Phosphorus	NO_2/NO_3
Stream 1, site 1	ppm	2,325	328	2,653		
Stream 1, site 2	ppm	2,135	411	2,546		
Stream 1, site 3	ppm	1,740	167	1,907	1.9	<0.01
Stream 2	ppm	1,470	259	1,729		
Stream 3	ppm	3,050	506	3,556		

3.0 Source Assessment

This section describes the potential sources in the Dump Lake watershed. The potential point and nonpoint sources are characterized by the best available information and literature values.

3.1 Point Sources

Pollutant sources under the CWA are typically categorized as either point or nonpoint sources. Point sources, according to 40 CFR 122.3, are defined as any discernable, confined, and discrete conveyance, including any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, concentrated animal feeding operation, landfill leachate collection system, vessel, or other floating craft from which pollutants are or may be discharged. The National Pollutant Discharge Elimination System (NPDES) Program, under CWA Sections 318, 402, and 405, requires permits for the discharge of pollutants from point sources. There are several types of permits under the NPDES permit program: effluent from facilities, municipal wastewater treatment plants, storm water from construction sites, and municipal separate storm sewer systems (MS4).

As of March 2003, discharge of storm water from construction activities disturbing between 1 and 5 acres must be authorized by an NPDES permit in addition to the requirements already in place for larger construction sites. The purpose of these NPDES permits is to eliminate or minimize the discharge of pollutants from construction activities. Since construction activities at a site are of a temporary, relatively short-term nature, the number of construction sites covered by the general permit at any given time will vary. The target for these areas is the same range as the TMDL target of 0.75 to 0.44 ton/acre/year. The WLAs provided to the NPDES-regulated construction activities and MS4s will be implemented as best management practices (BMPs) as specified in Mississippi's General Stormwater Permits for Small Construction, Construction, and Phase I & II MS4 permits. It is not technically feasible to incorporate numeric sediment limits into construction storm water or MS4 permits at this time. WLAs should not be construed as numeric permit limits for construction or MS4 activities. Properly designed and well-maintained BMPs are expected to provide attainment of WLAs.

A review of Mississippi automated resource information system discharge elimination file determined no permitted point source discharges are located within the watershed. The towns within the Dump Lake watershed are small and according to the final Phase II Storm water NPDES regulations are not considered regulated small MS4s at the present time. However, sediment loadings from NPDES-regulated construction activities and MS4s are considered point sources of sediment to surface waters. These discharges occur in response to storm events and are included in the WLA of this TMDL.

3.2 Nonpoint Source Data

Nonpoint sources in the watershed might also contribute pollutants to the lake. Nonpoint sources represent contributions from diffuse, nonpermitted sources. Exceptions to this are where some aquaculture facilities (which are discrete and nonpermitted sources), and where storm water collection systems are in place regulating the runoff as a point source since the runoff is delivered to the receiving water body though a conduit. Nonpoint sources include both precipitation-driven and non-precipitation-driven events such as contributions from groundwater; septic systems; direct deposition of pollutants from wildlife, livestock, or atmospheric fallout.

Nonpoint sources contribute sediment and oxygen-consuming loads into the waters of the Dump Lake watershed. On the land surface, oxygen-consuming constituents accumulate over time and wash off during rain events. As the runoff transports the sediment over the land surface, more oxygen-consuming constituents are collected and carried to the stream. The net loading into the stream is determined by the local watershed hydrology.

3.2.1 Agricultural Sources

The Mississippi Valley is one of the most intensively agricultural areas in the United States. The flat, fertile soils produce a variety of crops including cotton, corn, and soybeans. Cultivated and non-cultivated agricultural lands cover 27 percent and 17 percent, respectively, of the Dump Lake watershed area and are a source of sediment and nutrients. Cotton is the major crop in the Dump Lake watershed representing 72 percent of the total cultivated agriculture land and 19 percent of the total watershed area. Corn and Soybeans represent 17 percent and 9 percent, respectively, of the total cultivated agriculture land and 4.5 percent and 1.3 percent, respectively, of the total watershed area. Additional crops include: sorghum, snap beans, other small grains, rice, and winter wheat.

3.2.2 Aquaculture

The production of catfish is the largest aquaculture enterprise in the United States. Catfish ponds located in the Mississippi Valley account for approximately 78 percent of the total land area devoted to catfish production (EPA, 2002). The majority of the catfish ponds in the Mississippi Valley are groundwater fed, earthen levee ponds. The discharge of sediments rich in oxygen-consuming substances from catfish ponds occurs during drainage and overflow events. Drainage occurs occasionally, an average of once every 6 years for most ponds, when ponds are drained for harvesting or structural repairs. However, overflow from ponds occurs more often when the pond level rises due to precipitation events. Therefore, in this analysis, the ponds are treated as non point sources. Common pond management practices that reduce the frequency of pollutant discharges include managing pond levels to maintain water storage potential and reducing the frequency of pond drainage for cleaning and repairs. These practices are currently used in most catfish ponds in Mississippi (Tucker et al, 1996). A complex of catfish ponds covering approximately 38 acres, approximately 0.26 percent of the watershed area, is present in the Dump Lake watershed.

3.2.3 Septic Systems

Septic systems are not likely to be a significant source of organic material in the Dump Lake Watershed. Yazoo County has a total of 10,015 housing units (Table 3-1). Only a portion of these are located within the Dump Lake Watershed. Since the number of dwellings within the lake's watershed is small, septic systems were omitted from the analysis. Loads from septic systems were considered insignificant because the extensive agricultural areas are much larger sources when compared with the relatively low population density in the watershed.

Table 3-1. Yazoo County Housing Characteristics

	Total	Percent
Total housing units	10,015	100.0
1-unit detached	6,724	67.1
In building with 10 or more units	186	1.9
Mobile homes	1,854	18.5
Lacking complete plumbing facilities	210	2.1
Occupied units	9,178	91.6
Vacant units	837	8.4
For seasonal, recreational, or occasional use	72	0.7

Source: US DOC, Census, 2001.

3.2.4 Groundwater

The Mississippi River alluvial aquifer underlies the Mississippi River alluvial plain known as the Delta. The alluvial aquifer is the most heavily pumped aquifer in Mississippi (Arthur, 2001), of which 98 percent is for agriculture. According to the USGS, "the aquifer receives water vertically from precipitation, internal streams and lakes, and locally from the Cockfield and Sparta aquifers where they directly underlie the alluvial aquifer. The alluvial aquifer also discharges water to the underlying aquifers, and during extended periods with no surface runoff, to the Mississippi River and to the internal streams and lakes"(Arthur, 2001).

The water quality of the alluvial aquifer is well suited for agriculture but less suited for municipal and some industrial use. It is commonly a hard, bicarbonate type. It contains appreciable amounts of manganese and dissolved iron concentrations usually greater than 3.0 mg/L. According to the USGS, nutrient concentrations are generally low. All nitrate concentrations have been below the EPA drinking water standard of 10 mg/L (Kleiss et al, 1999).

3.2.5 Background Sources

TMDL load allocation must consider the natural background loading of a pollutant. For this TMDL, the contributions of sediment and organic material from forested areas was considered be the background load. Forested land, which includes bottomland hardwood forest, upland scrub, and riverine swamp, covers 56 percent of the Dump Lake watershed. Sediment contributions are generated from forested areas and other non-anthropogenic areas. While present, they are generally lower than those from disturbed land uses. Forested areas that are subject to silviculture and other forestry activities may exhibit elevated sediment contributions if Voluntary Best Management Practices for Forestry in Mississippi are not implemented. The monitoring data for the Dump Lake watershed were insufficient to separate natural forest loadings from other forest sources.

The yield of oxygen-consuming substances from forested land is generally low compared to other land uses because the dense vegetative cover stabilizes soil, reduces rainfall impact, and in many cases encourages uptake of nutrients.

4.0 Technical Approach

The objective of this Section is to present key issues considered for TMDL development, and technical approaches that fulfill the TMDL requirements.

4.1 Technical Approach Selection

The technical approach selected for TMDL development was based on evaluation of the following criteria (USEPA, 1991).

- Technical Criteria
- Regulatory Criteria

Technical criteria refer to the model's simulation of the physical system in question, including watershed, and stream or lake characteristics and processes and constituents of interest. Regulatory criteria make up the constraints imposed by regulations, such as water quality standards or procedural protocol.

Key technical factors that were considered in identifying the appropriate analytical approach for the sediment/siltation impairments include

- Sediment loads are contributed only by nonpoint sources.
- Erosion and sediment transport generally occur as a result of rainfall events.
- Sedimentation problems in the lake and its tributaries are a cause of cumulative contributions.
- Insufficient monitoring data are available in the watershed to evaluate the magnitude of stream channel and bank erosion.

Key technical factors that were considered in identifying the appropriate analytical approach for the nutrient and organic enrichment/low DO impairments include

- Oxygen-demanding substances (including nutrients) are contributed only by nonpoint sources in this watershed. There are currently no NPDES permitted point sources located in this watershed.
- Oxygen-demanding substances are contributed both from the land surface (as a results of rainfall events) and from the subsurface (due to groundwater contributions).
- The annual load of oxygen-demanding substances is responsible for the accumulated benthic blanket of the water body, which in turn, is expressed as sediment oxygen demand (SOD).

A properly designed and applied technical approach provides the source-response linkage component of the TMDL and enables accurate assimilative capacity assessment and allocation proposition. A water body's assimilative capacity is determined through adherence to predefined water quality criteria (i.e., regulatory considerations).

Mississippi's applicable water quality standards were presented earlier in this report and provide the basis for establishing appropriate TMDL targets. For sediment/siltation, this standard is narrative, however, for low DO, these standards are numeric. Instream DO target for this TMDL is a daily average of not less than 5.0 mg/L. The instantaneous minimum portion of the DO standard was considered when establishing the instream target for this TMDL. However, it was determined that using the daily average standard with the conservative modeling assumptions would be sufficiently protective of the instantaneous minimum standard.

Based on the considerations identified above, the technical approach to address sediment/siltation and organic enrichment/low DO impairments in Dump Lake includes a combination of watershed and lake water quality models.

- A simplified watershed model to predict runoff and loadings of sediment, nutrients, and organic material to the tributaries and lake to address both sediment/siltation and organic enrichment/low DO impairments
- Receiving water model of the organic enrichment/low DO in Dump Lake for prediction of instream DO concentrations for comparison to selected endpoints.
- Siltation rate analysis for the lake.

The technical approach to TMDL development must consider the dominant watershed and inlake processes. Pollutant loading in Dump Lake watershed is primarily from non-point or diffuse sources, which are typically rainfall-driven and relate to surface runoff and subsurface discharge to a stream. Apart from aquaculture within the watershed, which is treated as a point source, no point sources exist in the watershed. The inlake processes include advective and diffusive transport and nutrient cycling. The approach will provide a hydrologic, sediment, and nutrient-loading budget for the watershed that can be linked to an inlake and instream water quality model to assess the inlake water quality.

4.2 Modeling

Both watershed and receiving water models were used to identify the TMDL for sediment and organic enrichment. To ease the discussion, the models are discussed by impairment in the following subsections.

4.2.1 Sedimentation

The Generalized Watershed Loading Function model (GWLF) (Haith and Shoemaker, 1987) was selected to simulate the loading of sediment and oxygen consuming substances from the Dump Lake watershed. The GWLF model has been widely used to estimate sediment and nutrient loads from agricultural watersheds. The GWLF model uses the Soil Conservation Service Curve Number (SCS-CN) approach to model surface runoff and the Universal Soil Loss Equation (USLE) algorithm to model erosion and sediment yield. The SCS-CN and USLE methods are a component of other watershed models including the Agricultural Non Point Source Loading (AGNPS) model and the Soil and Water Assessment Tool (SWAT).

GWLF is an aggregate distributed/lumped parameter watershed model. For surface loading, it is distributed in the sense that it allows multiple land use/cover scenarios. Each category area is assumed to be homogeneous with respect to various attributes considered by the model. Additionally, the model does not spatially distribute the source areas, but aggregates the loads from each area into a watershed total. In other words, there is no spatial routing. For subsurface loading, the model acts as a lumped parameter model using a water balance approach. No distinctly separate areas are considered for subsurface flow contributions. Daily water balances are computed for an unsaturated zone as well as for a saturated subsurface zone, where infiltration is computed as the difference between precipitation and snowmelt minus surface runoff plus evapotranspiration. Monthly calculations are made for sediment and nutrient loads, based on daily water balance totals that are summed to give monthly values.

The sediment accumulation in Dump Lake can be assessed using trap efficiency calculations. The Brune method (USACE, 1989) provides a widely used trap efficiency estimation method for lakes and reservoirs, using a graphical relationship between trap efficiency and the ratio of water body volume to annual volumetric inflow. Using the volume of the lake and estimated annual inflows from the GWLF model, the trap efficiency (%) of the lake can be estimated. Based on the trap efficiency, the siltation rate can be estimated. Additional modeling information may be found in Appendix A.

4.2.2 Organic Enrichment/Low DO and Nutrients

The Dump Lake system is approximately 3.5 miles long and approximately 0.18 miles wide. The existing calibrated CE-QUAL-W2 (W2) (Cole and Buchak, 1995) hydrodynamic model for this system will be used to simulate eutrophication processes. The model is vertically and horizontally two-dimensional and simultaneously simulates hydrodynamics and the transport and transformation of water quality variables. The model was configured with 10 longitudinal segments, each with lengths ranging from 250 to 800 meters long, and a maximum of three 1- meter thick vertical layers. The total number of active model cells was 29. Longitudinal and vertically varying cell widths ranged from 415 meters at the surface to 15 meters at the bottom. In general the simulated DO followed a seasonal trend. No calibration could be performed at this time due to lack of inlake monitoring data. Additional modeling information about model set up, assumptions, and limitations may be found in Appendix B.

Once the model setup and calibration were complete. The model was run for the selected critical period from 1997 to 2000 under baseline conditions. The baseline model run reflects the existing conditions for these years without any reduction to the oxygen-consuming loadings from the watershed. The model was then run using a trial-and-error process to determine the maximum total biochemical oxygen demand (TBODu) loads from the watershed which would not exceed water quality standards for DO at the mid-depth. These constituted the load reduction scenarios. The model simulation results were analyzed at the mid-depth with the daily average DO criteria. The DO standard was applied at mid-depth of the lake, as the average depth of the lake was less than 10 feet. Model segment 6 (Figure B-1 in Appendix B) was chosen as the location for evaluating the TMDL as it exhibited the poorest water quality conditions in the lake based on model results.

Model results showed that when a 45 percent reduction was included, the water quality standard was met at mid-depth. Figure 4-1 shows the baseline and the 45 percent load reduction case at mid-depth for the daily average DO at model segment 6 (Figure B-1 in Appendix B).

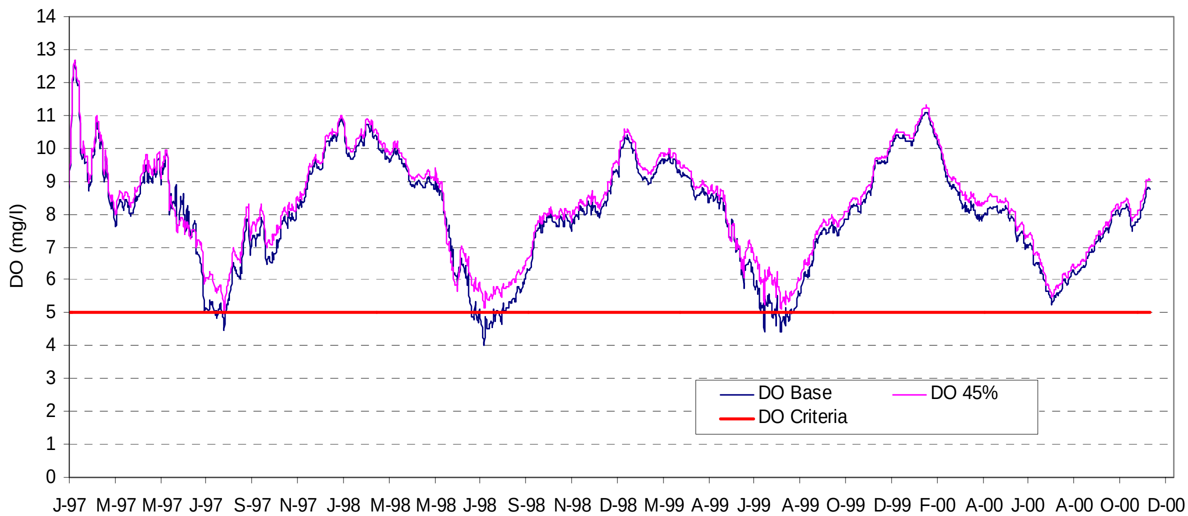

Figure 4-1. Daily Average DO at Mid-Depth

4.2.3 Modeling Assumptions

Some of the major underlying assumptions for this analysis include the following:

General

- Meteorological data from Jackson, Mississippi were assumed to be representative of the entire watershed contributing to the lake, although the station is located outside of the watershed. The Jackson station was used because it is the nearest station to Dump Lake that has complete meteorological records.
- The watersheds delineated were based on topographic data and available stream and channel coverages. Data regarding flow diversions to or from other watersheds were not available and therefore not considered in the analysis.

Sedimentation Analysis

- The lake's life span was estimated by predicting the amount of sediment contributed to the lake over time and determining the reservoir volume reduced by the sediment. Sediment reaching the lake was assumed to be deposited homogeneously over the entire lake bottom. In reality, however, sediment deposition varies depending on many factors, such as bathymetry. The life of the lake was assumed to be exhausted when the lake surface area was reduced by approximately 50 percent.

- The lake's sediment-trapping efficiency was based on Brune's method (Chow, 1953).
- The sediment distribution was assumed to be an equal mix between sand, silt, and clay particles.
- Sedimentation at the land use-level was predicted using USLE, and only a portion of this load was delivered to the lake. The percentage of eroded sediment delivered to the lake was based on a sediment delivery ratio.
- Available data indicated that no timber harvesting was occurring within the watershed. Therefore, forested land was assumed to be consistent throughout the watershed, with respect to sediment load contributions.
- Sedimentation prediction assumed that unpaved roads were not playing a major role in sediment contribution to the lake.
- Land management practices including reduced tillage, cover crops and detention ponds are widely used in the Mississippi Delta area (Yuan and Binger, 2002). Therefore, agricultural land in the watershed was assumed to be managed under moderate tillage.

Organic Enrichment/Low DO and Nutrients

- Monthly loads are assumed to sufficiently represent loading variability to the lake model.
- Kinetic parameters from the Wolf Lake W2 model were assumed to be applicable to Dump Lake since it was in the same vicinity.
- The watershed model gives an estimate of the total phosphorus and total nitrogen. These loadings were split based on the nutrient ratios determined from inlake monitoring data to provide the required loadings (as per W2 model requirements) of dissolved and particulate organic material, ammonia, nitrate-nitrite, and ortho-phosphorus that feed into the W2 model. Nutrient ratios from Wolf Lake were used since no inlake monitoring exists for Dump Lake to make an estimate of the nutrient ratios.
- Long-term contributions of nutrients and other oxygen-demanding substances to the lakes ultimately result in high SOD levels. Due to this relationship, during the allocation process SOD levels were reduced when incoming nutrient and oxygen-demanding substance reductions were made. Past lake studies using predictive sediment diagenesis models have suggested that the SOD is reduced by approximately half the percent reduction of incoming nutrients and oxygen-demanding substances (USEPA, 2002).
- The watershed model did not simulate DO and water temperature, therefore a number of assumptions were made regarding boundary conditions (inputs from the watershed) for the lake model. A DO concentration time series equal to 90 percent saturation was assumed for all inputs. Water temperatures feeding into

the lake were based on a generalized sine curve temperature time series (based on temperature data from Wolf Lake) and were used for both branches and their tributaries.

4.2.4 Limitations

A number of limitations were inherent in the analytical process due to the approach selected. Although these limitations, identified below, are present, the approach followed successfully resulted in TMDL identification. If additional data are collected for Dump Lake, many of these limitations can be addressed.

Sedimentation Analysis

- Stream-bank erosion was not explicitly considered in the analysis. Only surface erosion and delivery was considered.
- Sediment deposition varies depending on many factors, such as bathymetry. Sediment deposition was assumed to occur evenly over the entire lake area. The life of the lake was assumed to be exhausted when the lake surface area was reduced by approximately 50 percent.
- Forested land was assumed to be consistent throughout the watershed with respect to sediment load contributions.

Organic Enrichment/Low DO and Nutrients

- Sediment, nutrient, and oxygen flux data were not available for the lake. Collection of these data are important to further understand the overall sediment fluxes in the lake and their implications on DO levels. In the event that additional sediment flux data are collected, extending the existing reservoir model to consider predictive sediment diagenesis processes, which dynamically link sediment response to nutrient inputs, could provide a better long-term prediction of SOD. Presently, the CE-QUAL-W2 model does not include a sediment modeling system that directly interacts with the water column, i.e., there is no separate sediment compartment.
- The impact of sediment reduction on light extinction in the lake was not considered during the allocation process. It is possible that as sediment loads are reduced, more light will be available to algae in the lake. Light availability may result in increased algae growth and possibly greater DO concentration variability.

4.2.5 Recommendations

Although data collection activities are not planned at the present time, suggestions for data that could be used to refine the assumptions and address the limitations of the modeling effort are included in this report. Data collection would enable a detailed calibration and analysis of sedimentation and DO/organic enrichment dynamics in the lake. These data would ultimately lead to more refined TMDL values and load allocations.

General

- No flow gages are currently located within the watershed. Flow monitoring would provide valuable insight into the watershed's hydrology and support further evaluation of meteorological and land-based impacts on the lake.
- No information on lake level management (timing and release) at the low-flow weir is available.

Sedimentation Analysis

- Insufficient sediment monitoring data were available to perform a detailed evaluation of sedimentation and resuspension in the lake. Further evaluation of sedimentation spatially and temporally throughout the lake would provide a more precise estimation of the life span.
- Further analysis of stream channel morphology and evolution is recommended to identify the significance of stream-bank erosion to the lake's sedimentation rate. In the event that stream-bank erosion is found to play a major role in sediment contributions to the lake, simulation of stream channel evolution may be a useful analytical tool.
- Information on the forestry practices and best management methods in the watershed is recommended.
- Additional ground-truthing of unpaved road locations and their impact on sedimentation in the watershed is recommended.

Organic Enrichment/Low DO and Nutrients

- Water quality monitoring data within the lake are necessary to support model calibration and to understand, in more detail, dynamics of the lake. These data should be collected at multiple locations throughout the lake during different seasons, and they should include depth-variable temperature, DO, and nutrient samples; diurnal DO data; and algal bioassays.
- Water quality monitoring data for tributaries contributing to the lake are important in evaluating locational and source-specific pollutant contributions, as well as identifying seasonal and critical period trends. It is recommended that water quality samples be collected at multiple locations throughout the watershed for baseflow and storm-flow conditions.
- The relationship between sediment reduction, light extinction, and algae growth needs to be explored further. Sediment reduction levels, without an associated reduction in nutrients, may result in increased light availability and thus increased algae growth and diurnal DO variations. It is important to collect data that provides more insight into these dynamics.

5.0 TMDL Development

A TMDL for a given pollutant and water body is composed of the sum of individual WLAs for point sources, and LAs for both nonpoint sources and natural background levels. In addition, the TMDL must include a margin of safety (MOS), either implicitly or explicitly, to account for the uncertainty in the relationship between pollutant loads and the quality of the receiving water body. Conceptually, this definition is represented by the equation:

$$TMDL = \sum WLAs + \sum LAs + MOS$$

The TMDL is the total amount of pollutant that can be assimilated by the receiving water body while still achieving water quality standards. In TMDL development, allowable loadings from all pollutant sources that cumulatively amount to no more than the TMDL must be established and thereby provide the basis to establish water quality-based controls.

5.1 TMDL Water Quality Endpoints

One of the major components of a TMDL is the establishment of instream numeric endpoints, which are used to evaluate the attainment of acceptable water quality. Instream numeric endpoints represent the water quality goals that are to be achieved by meeting the load allocations specified in the TMDL. The endpoints allow for a comparison between observed instream conditions and conditions that are expected to restore designated uses. Specifications of numeric water quality endpoints or targets are discussed by pollutant below.

5.1.1 Sediment/Siltation

The water quality standard applicable for protection of aquatic life due to sediment is narrative. Thus, calculations that directly link the TMDL target to the standard are not possible. Because of this, the TMDL target was developed by evaluating the effect of using alternative tillage practices and increasing wooded areas in the watershed to approximate natural sediment loading conditions. Oxbow lakes are naturally dynamic systems and have limited life spans, typically filling with sediment over time (Monroe and Wicander, 1992). As a result, a reasonable goal for TMDL development is not necessarily to prevent sediment accumulation entirely, but to return the lake to its natural rate of sediment accumulation.

Interpretation of the standard using conservative judgment was necessary in order to link the narrative standard with a measurable TMDL target. Section III.3 of State of Mississippi Water Quality Criteria for Intrastate, Interstate and Coastal Waters states that "waters shall be free from materials attributable to municipal, agricultural, and other discharges producing … total suspended or dissolved solids, sediment, turbidity, or other conditions in such degree as to … render the waters injurious to public health, recreation or to aquatic life and wildlife…"[1]. In order to develop the target for this TMDL, MDEQ interpreted this standard to mean that sediment loads entering an oxbow lake from its watershed should be low enough so that they do not significantly alter the functional life-span of the lake.

The functional life-span of the oxbow lake is defined as the period in which the aquatic resource will adequately support recreational uses and aquatic life in the lake. For the purpose of this TMDL a functional life-span was defined to extend until approximately 50% of the lake surface area or 30% of the lake volume is filled with sediment. The rate at which the lake filled with sediment was calculated using a few simplifying assumptions. First, the GWLF model predicted the sediment loads reaching the lake from the watershed under various management practices. The portion of the sediment loads retained by the lake was estimated. Then, this sediment load was converted to a volume using a specific weight of 1 g/cm^3. The sediment volume was assumed to be distributed evenly over the lake surface. Finally, the functional life-span was calculated for each management practice as the time it takes for the sediment volume to fill approximately 50% of the lake's surface area. These processes are described in more detail in Appendix A.

The calculations used to estimate the life-span of the lakes, though based on several assumptions, represent a simulation of the actual sedimentation processes occurring in the lake. Since oxbow lakes are formed through a long, erosional process and, once formed, naturally fill with sediment over time, the goal of the TMDL is not to completely stop the natural sedimentation process. Rather, the TMDL is based on the theory that reducing the amount of controllable sediment that enters the lakes from the watershed, the functional life-span of the lakes will be prolonged. Reducing the amount of sediment entering the lakes may also improve aquatic community in the water body.

5.1.2 Organic Enrichment/Low DO and Nutrients

The endpoint for organic enrichment/low DO and nutrient TMDL development for Dump Lake is based upon the daily average of not less than 5.0 mg/L. It is assumed that using the daily average standard with the conservative modeling assumptions will be sufficiently protective of the instantaneous minimum standard.

Generally, an organic enrichment/low DO impairment suggests critical conditions in the water body that result from processes that link sources of nutrients and organic material to biological processes and DO levels. For this TMDL, organic enrichment has been expressed in terms of TBODu. TBODu represents the oxygen consumed by microorganisms while stabilizing or degrading carbonaceous and nitrogenous compounds under aerobic conditions over an extended time period. The carbonaceous compounds are referred to as CBODu and the nitrogenous compounds are referred to as NBODu. TBODu is equal to the sum of CBODu and TBODu.

$$\text{TBODu} = \text{CBODu} + \text{NBODu} \qquad [1]$$

[1] MDEQ. Adopted October 24, 2002.

The watershed model gives an estimate of oxygen-consuming substances from which an estimate of the TBODu has been made. The CBODu load can be estimated from the stoichiometric relationship between the total organic carbon (TOC) and oxygen, which is 2.67 pounds of oxygen per pound of carbon consumed (Thomann and Mueller, 1987). Since the watershed model does not directly simulate TOC, an indirect estimate of TOC can be made based on the stoichiometric equivalent between organic matter (OM) and carbon. OM can be converted to TOC using a stoichiometric relationship, which is 0.45 times the OM (Cole and Buchak, 1995). Thus, the CBODu can then be determined from the OM by multiplying it by 1.2 (0.45 x 2.67).

In order to convert the ammonia nitrogen (NH_3-N) loads and oxygen demand, a factor of 4.57 pounds of oxygen per pound of NH_3-N oxidized to nitrate nitrogen (NO_3-N) was used (USEPA, 1993). Using this factor is a conservative modeling assumption because it assumes that all of the ammonia is converted to nitrate through nitrification, which is not necessarily accurate. The oxygen demand caused by nitrification of ammonia is equal to the NBODu load. Thus TBODu can be estimated using the revised equation:

$$\text{TBODu} = 1.2\ \text{OM} + 4.57\ NH_3\text{-N} \qquad [2]$$

5.2 Critical Condition and Seasonality

40 CFR Section 130 requires that critical environmental conditions and seasonal environmental variations be considered in TMDLs. The requirements are designed to simultaneously ensure that water quality is protected during times when it is most vulnerable, and take into account changes in streamflow and loading characteristics as a result of hydrological or climatological variations. These conditions are important because they describe the factors that combine to cause exceedance of water quality standards and can help identify necessary remedial actions.

5.2.1 Sediment/Siltation

The sediment analysis considered seasonality in the loading through the simulation of monthly watershed loadings based on historic precipitation records. The evaluation of sediment effects on the lake was considered for the average annual conditions representing the response to long term, cumulative siltation. The TMDL and LA are presented as an annual average loading consistent with the type of impairment (siltation) and water body type (oxbow lake). Reduction of the average annual load is needed in order to meet water quality standards.

The critical conditions for the sediment TMDL are selected to evaluate the type of impairment (siltation) and the type of water body (oxbow lake). Protection of the lake condition requires the control of long-term loadings and accumulation of sediment. The lake condition is evaluated based on mean siltation rates in response to long-term annual loading and trapping of sediments in the lake.

5.2.2 Organic Enrichment/ Low DO and Nutrients

The organic enrichment/low DO and nutrients analysis considered seasonality in the loading through the simulation of monthly watershed loadings based on historic precipitation records. Long-term simulation of the lake model under varying precipitation and meteorological conditions takes the seasonality into account.

Historic precipitation values were evaluated from 1985 to 2000 (Figure 5-1) at the Yazoo City precipitation station (see Figure B-3 in Appendix B for the location of the Yazoo City station). The years 1997 to 2000 were chosen as the TMDL simulation period as these years were not extreme and were close to the annual average precipitation. This period had a wet year, 1997, and a dry year, 2000 (Figure 5-1). Extreme years (very dry or wet) were not considered for the TMDL. Also the period from 1997 through 2000 corresponded to the years where the most complete dataset of hourly surface airways meteorological data was available from the Jackson, Mississippi, surface airways station (Figure B-4 in Appendix B).

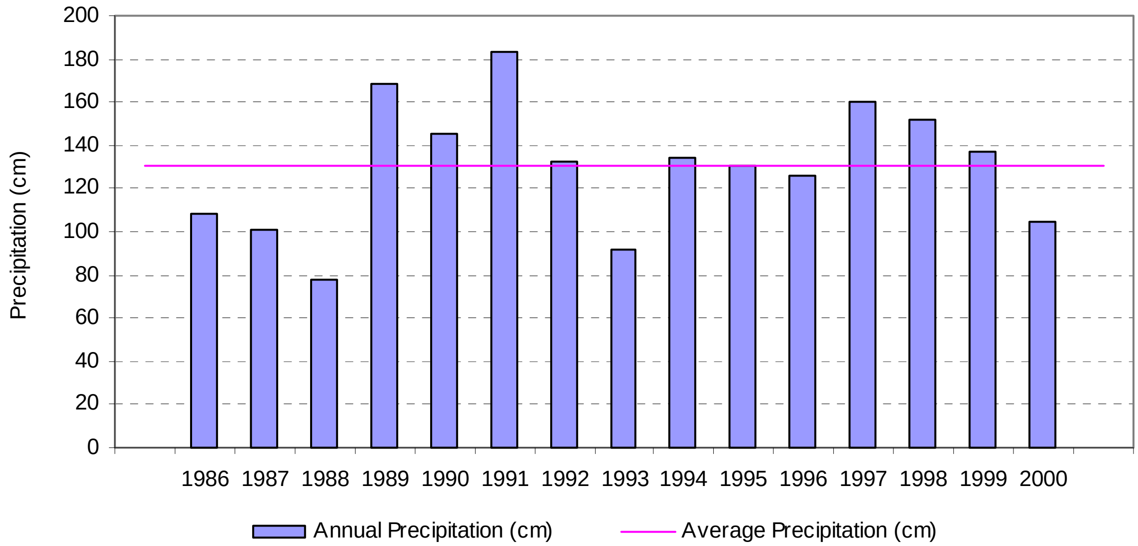

Figure 5-1. Historic Precipitation 1985-2000 (Yazoo City)

Simulation results from the inlake model for this period showed that 1997 was the critical period and meeting the MDEQ DO criteria during this period would be used to determine the TMDL. As shown in Figure 5-2, the simulation period exhibited a wide range of hydrologic conditions with wet spring and dry summer. Lakes are also typically conducive to eutrophication under these conditions. It may be noted that these years had some relatively dry summer months as well.

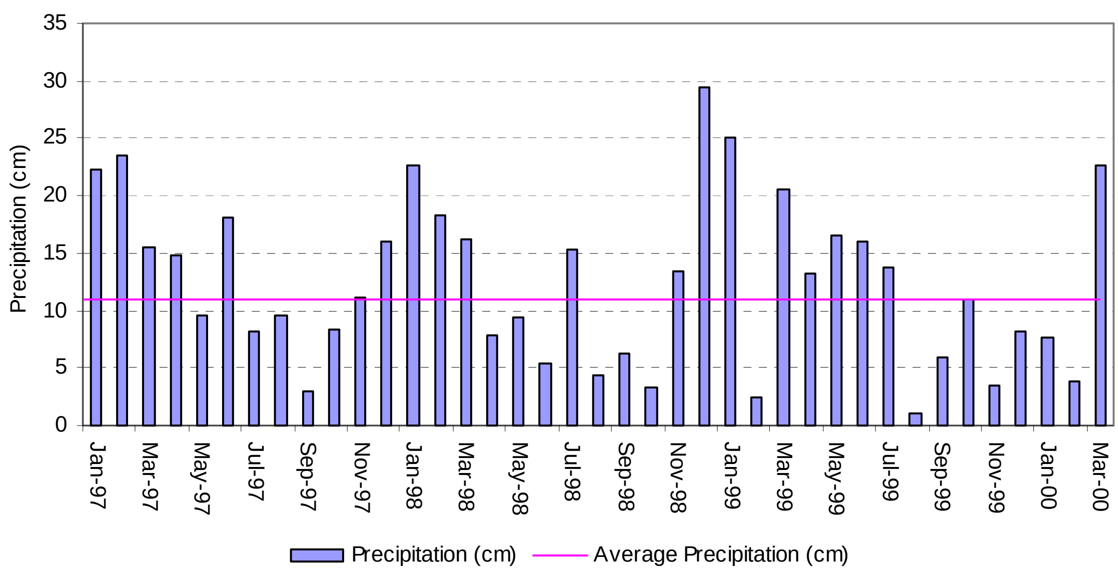

Figure 5-2. Monthly Precipitation 1997-2000 (Yazoo City)

5.3 Sediment-Loading Analysis

The sediment-loading analysis was based on the long-term average sedimentation rate. Table A-6 in Appendix A provides the computed mean sedimentation rate of the lake for six possible land management scenarios: (1) existing condition, (2) conventional tillage, (3) 50 percent wooded and moderate tillage, (4) no tillage, (5) 50 percent wooded no tillage, and (6) 100 percent wooded. The life span of the lake under these six conditions is presented in Figure 5-3.

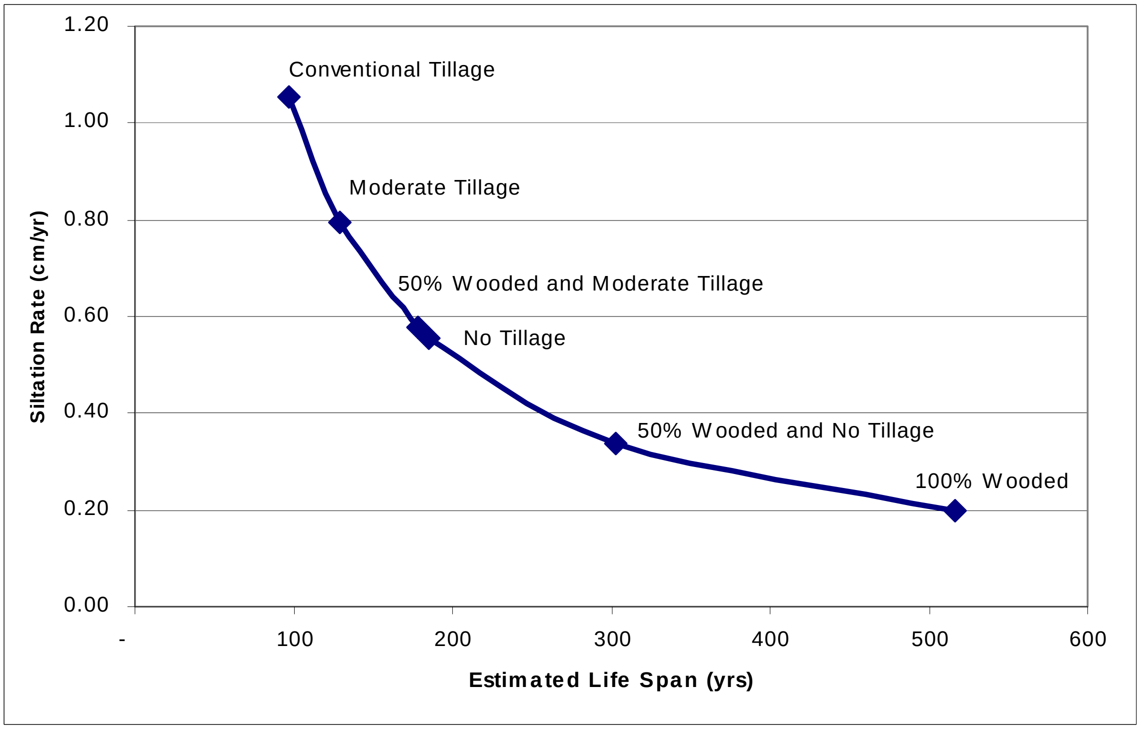

Figure 5-3. Estimated Life span for Scenarios

These scenarios are based on example land management practices that would result in varying life spans for the lake. The target range was selected in order to achieve a reasonable improvement in sedimentation rates. A range of rates from 0.58 cm/year to 0.34 cm/year was identified as a long-term average sedimentation endpoint. While this corresponds to the scenarios of 50 percent wooded and moderate tillage to 50 percent wooded and no tillage, this TMDL is not requiring that these particular BMPs be implemented in the watershed. The reductions can be achieved through various combinations of BMPs that could reasonably be put in place in the Dump Lake watershed. This TMDL encourages the use of land management practices, including planting additional forested area, and riparian strips and using conservative tillage practices in agricultural areas. As shown in Figure 5-3, the use of these land management practices will significantly extend the life span of Dump Lake.

5.4 TMDL Allocations of Sediment

According to the model, a sedimentation rate of 0.58 cm/year occurred when the sediment load from the watershed was reduced by 31 percent. A sedimentation load reduction of 59 percent gave an estimated sedimentation rate of 0.34 cm/year. This range of sedimentation rates is estimated to extend the life span of the lake from approximately 129 years under existing conditions to between 175 and 300 years.

This reduction was distributed among the different land use categories in the watershed, based on load reduction feasibility (Table 5-1). A reduction was applied to the “other” land use category, although the load may be considered a non-anthropogenic background land use, since it is a significant contributor of sediment. The “other” land use category consists of bottomland hardwood forests, shrubs, woods, and swamp. No reduction was applied to the “residential” or the “aquaculture” land use categories since these land uses in the Dump Lake watershed are negligible, comprising less than 1 percent of the total land use in the watershed.

Table 5-1. Load Reduction Scenario - Sedimentation Rate 0.58 cm/year

LAND USE	BASELINE (ton/year)	REDUCTION (ton/year)	REDUCTION (%)
Agriculture Cultivated	8,891	2,760	31
Agriculture Noncultivated	2,147	660	31
Aquaculture	1	0	0
Residential	24	0	0
Other	3,583	1,097	31
Total	**14,645**	**4,517**	**31**

Table 5-2. Load Reduction Scenario - Sedimentation Rate 0.34 cm/year

LAND USE	BASELINE (ton/year)	REDUCTION (ton/year)	REDUCTION (%)
Agriculture Cultivated	8,891	5,285	59
Agriculture Noncultivated	2,147	1,275	59
Aquaculture	1	0	0
Residential	24	0	0
Other	3,583	2,127	59
Total	**14,645**	**8,687**	**59**

The TMDLs for the selected range of sedimentation rates are presented in Tables 5-3 and 5-4. Based on the model, the sediment load to achieve a sedimentation rate of 0.58 cm/year is 0.75 ton/acre/year, and the sediment load to achieve a sedimentation rate of 0.34 cm/year is approximately 0.44 ton/acre/year. It should be stressed that these numbers are only approximations, based on an interpretation of the limited data available for Dump Lake. There were many assumptions and limitations used in calculating these loads. Collection of additional data or the consideration of other land use management scenarios may result in refinement or modifications of the TMDLs.

Sediment loadings from NPDES-regulated construction activities and MS4s are considered point sources of sediment to surface waters. These discharges occur in response to storm events and are included in the WLA of this TMDL as the same target yield as the TMDL of 0.75 to 0.44 ton/acre/year.

Table 5-3. TMDL for Sedimentation Rate of 0.58 cm/year for Dump Lake

Pollutant	**WLA (ton/acre/year)**	**LA (ton/acre/year)**	**MOS**	**TMDL (ton/acre/year)**
Sediment	0.75	0.75	Implicit	0.75

Table 5-4. TMDL for Sedimentation Rate of 0.34 cm/year for Dump Lake

Pollutant	**WLA (ton/acre/year)**	**LA (ton/acre/year)**	**MOS**	**TMDL (ton/acre/year)**
Sediment	0.44	0.44	Implicit	0.44

5.5 TMDL Allocations of TBODu

A 45 percent reduction in the annual watershed loading is recommended to achieve the inlake DO criteria. This percent reduction could be distributed among the different land use categories in the watershed, based on load-reduction feasibility (Table 5-5). No reduction was applied to the “other” land use category, which was considered a background (non-anthropogenic) land use and consists of bottomland hardwood forests, shrubs, woods, and swamp. No reductions were applied to the “residential” land use category since this was negligible and comprised less than 1 percent of the total land use in the watershed. Accordingly the reductions were adjusted among the remaining three land uses. The load-reduction scenarios given in Table 5-5 are just one example of how land management could be modified in order to reduce pollutant loadings in Dump Lake. Other management scenarios that have not been described in this report are possible.

Table 5-5. Load Reduction Scenarios

	BASELINE		**REDUCTION**		
LAND USE	**NBODu (lb/day)**	**CBODu (lb/day)**	**NBODu (lb/day)**	**CBODu (lb/day)**	**Reduction (%)**
Agriculture Cultivated	93.4	175.7	53.7	101	58
Agriculture Noncultivated	19.9	40.6	11.4	23.4	57
Aquaculture	0.9	1.3	0.5	0.8	55
Other	27.7	55.8	0	0	0
Residential	3.7	6.0	0	0	0
Total	**145.6**	**279.5**	**65.7**	**125.2**	**45**

Based on these reductions the TBODu was computed using equation [2] described in Section 4.2.2, and the TMDL is presented in Table 5-6. The TMDL for TBODu was computed to be approximately 234 lb/day.

Table 5-6. TMDL for TBODu for Dump Lake

Pollutant	WLA (lb/day)	LA (lb/day)	MOS	TMDL (lbsday)
CBODu	0	154	Implicit	154
NBODu	0	80	Implicit	80
TBODu	0	234	Implicit	234

5.6 Evaluation of Ammonia Toxicity

Ammonia must not only be considered due to its effect on dissolved oxygen in the receiving water, but also its toxicity potential. Ammonia nitrogen concentrations can be evaluated using the criteria given in 1999 Update of Ambient Water Quality Criteria for Ammonia (EPA-822-R-99-014). The maximum allowable instream ammonia nitrogen (NH_3-N) concentration at a pH of 7.0 and stream temperature of 26°C is 2.82 mg/l. Based on the model results, this criteria was not exceeded in Dump Lake under the current NH_3-N loads

5.7 Margin of Safety

The MOS one of the required elements of a TMDL. There are two basic methods for incorporating the MOS (USEPA, 1991):

- Implicitly incorporate the MOS using conservative model assumptions to develop allocations.
- Explicitly specify a portion of the total TMDL as the MOS; use the remainder for allocations.

The MOS for this TMDL was expressed implicitly through implicit conservative assumptions. Specific conservative assumptions include:

- The loadings calculated by the nonpoint source model (GWLF) were derived using conservative assumptions in the selection of nutrient potency and sediment loading factors. For example, a minimum slope of 0.5 percent was used for USLE calculations, although lower sloped occur. Also, the sediment volume in the lake was not reduced for compaction. Finally, the loss of approximately half the surface area of the lake was used as an endpoint for lake life span.
- The use of conservative assumptions in developing the loading model results in relatively high loads and slightly larger required load reductions. One example of this is that the reduction of oxygen demanding substances was based on the most critical year during the simulation period.

5.8 Reasonable Assurance

This component of TMDL development does not apply. There are no point sources requesting a reduction based on LA components and reductions.

5.9 Public Participation

This TMDL will be published for a 30-days public in the statewide newspaper. The public will be given an opportunity to review the TMDL and submit comments. MDEQ also distributes all TMDLs at the beginning of the public notice to those members of the public who have requested to be included on a TMDL mailing list. TMDL mailing list members may request to receive the TMDL reports through either email or the postal service. Anyone wishing to become a member of the TMDL mailing list should contact Greg Jackson at (601) 961-5098 or Greg_Jackson@deq.state.ms.us.

All comments received during the public notice period and at any public hearings become a part of the record of this TMDL. All comments will be considered in the submission of this TMDL to EPA Region 4 for final approval.

5.10 Future Monitoring

MDEQ has adopted the Basin Approach to water quality management, a plan that divides Mississippi's major drainage basins into five groups. During each yearlong cycle, MDEQ's resources for water quality monitoring will be focused on one of the basin groups. During the next monitoring phase in the Yazoo Basin, Dump Lake may receive additional monitoring to identify any change in water quality. The additional monitoring may allow refinements of the assumptions used to calculate this TMDL.

5.11 Conclusion

To evaluate the relationship between the sources, their loading characteristics, and the resulting conditions in the lake, a combination of analytical tools was used. This involved source response linkage between the GWLF watershed model for the Dump Lake watershed with a 2-dimensional inlake water quality model for Dump Lake. The sediment load estimates from the GWLF model were used in the sedimentation rate analysis for the lake. The sedimentation rate analysis was based on a long-term average sedimentation rate that assessed a range of land management practices. A range of 0.58 cm/year to 0.34 cm/year was identified as a long-term average sedimentation endpoint based on the example land management scenarios included in this TMDL.

A 45 percent reduction of the oxygen demanding source loadings coming from the watershed was recommended to meet the prescribed DO criteria of a daily average of 5 mg/L. A 31 to 59 percent reduction of sediment load was also recommended to address the siltation loading. The sediment TMDL was computed to be approximately 0.75 tons/acre/year to 0.44 tons/acre/year of sediment for the range of selected endpoints. The organic enrichment/low DO TMDL for TBODu was computed to be approximately 234 lb/day.

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Definitions

Ammonia: Inorganic form of nitrogen (NH_3); product of hydrolysis of organic nitrogen and denitrification. Ammonia is preferentially used by phytoplankton over nitrate for uptake of inorganic nitrogen.

Ammonia Nitrogen: The measured ammonia concentration reported in terms of equivalent ammonia concentration; also called total ammonia as nitrogen (NH_3-N)

Ammonia Toxicity: Under specific conditions of temperature and pH, the un-ionized component of ammonia can be toxic to aquatic life. The un-ionized component of ammonia increases with pH and temperature.

Ambient Stations: A network of fixed monitoring stations established for systematic water quality sampling at regular intervals, and for uniform parametric coverage over a long-term period.

Assimilative Capacity: The capacity of a body of water or soil-plant system to receive wastewater effluents or sludge without violating the provisions of the State of Mississippi Water Quality Criteria for Intrastate, Interstate, and Coastal Waters and Water Quality regulations.

Background: The condition of waters in the absence of man-induced alterations based on the best scientific information available to MDEQ. The establishment of natural background for an altered water body may be based upon a similar, unaltered or least impaired, water body or on historical pre-alteration data.

Biological Impairment: Condition in which at least one biological assemblage (e.g., fish, macroinvertabrates, or algae) indicates less than full support with moderate to severe modification of biological community noted.

Carbonaceous Biochemical Oxygen Demand: Also called CBODu, the amount of oxygen consumed by microorganisms while stabilizing or degrading carbonaceous compounds under aerobic conditions over an extended time period.

Calibrated Model: A model in which reaction rates and inputs are significantly based on actual measurements using data from surveys on the receiving water body.

Critical Condition: Hydrologic and atmospheric conditions in which the pollutants causing impairment of a water body have their greatest potential for adverse effects.

Daily Discharge: The "discharge of a pollutant" measured during a calendar day or any 24-hour period that reasonably represents the calendar day for the purposes of sampling. For pollutants with limitations expressed in units of mass, the daily discharge is calculated as the total mass of the pollutant discharged over the day. For pollutants with limitations expressed in other units of measurement, the daily average is calculated as the average.

Designated Use: Use specified in water quality standards for each water body or segment regardless of actual attainment.

Discharge Monitoring Report: Report of effluent characteristics submitted by an NPDES-permitted facility.

Dissolved Oxygen: The amount of oxygen dissolved in water. It also refers to a measure of the amount of oxygen that is available for biochemical activity in a water body. The maximum concentration of dissolved oxygen in a water body depends on temperature, atmospheric pressure, and dissolved solids.

Dissolved Oxygen Deficit: The saturation dissolved oxygen concentration minus the actual dissolved oxygen concentration.

DO Sag: Longitudinal variation of dissolved oxygen representing the oxygen depletion and recovery following a waste load discharge into a receiving water.

Effluent Standards and Limitations: All state or federal effluent standards and limitations on quantities, rates, and concentrations of chemical, physical, biological, and other constituents to which a waste or wastewater discharge may be subject under the federal act or the state law. This includes, but is not limited to, effluent limitations, standards of performance, toxic effluent standards and prohibitions, pretreatment standards, and schedules of compliance.

Effluent: Treated wastewater flowing out of the treatment facilities.

First Order Kinetics: Describes a reaction in which the rate of transformation of a pollutant is proportional to the amount of that pollutant in the environmental system.

5-Day Biochemical Oxygen Demand: Also called BOD5, the amount of oxygen consumed by microorganisms while stabilizing or degrading carbonaceous or nitrogenous compounds under aerobic conditions over a period of 5 days.

Groundwater: Subsurface water in the zone of saturation. Groundwater infiltration describes the rate and amount of movement of water from a saturated formation.

Impaired Water Body: Any water body that does not attain water quality standards due to an individual pollutant, multiple pollutants, pollution, or an unknown cause of impairment.

Land Surface Runoff: Water that flows into the receiving stream after application by rainfall or irrigation. It is a transport method for nonpoint source pollution from the land surface to the receiving stream.

Load Allocation (LA): The portion of a receiving water's loading capacity attributed to or assigned to nonpoint sources (NPS) or background sources of a pollutant

Loading: The total amount of pollutants entering a stream from one or multiple sources.

Mass Balance: An equation that accounts for the flux of mass going into a defined area and the flux of mass leaving a defined area; the flux in must equal the flux out.

Nonpoint Source: Pollution contained in runoff from the land. Rainfall, snowmelt, and other water that does not evaporate become surface runoff and either drain into surface waters or soak into the soil and finds their way into groundwater. This surface water may contain pollutants that come from land use activities such as agriculture, construction, silviculture, surface mining, disposal of wastewater, hydrologic modifications, and urban development.

Nitrification: The oxidation of ammonium salts to nitrites via Nitrosomonas bacteria and the further oxidation of nitrite to nitrate via Nitrobacter bacteria.

Nitrogenous Biochemical Oxygen Demand: Also called NBODu, the amount of oxygen consumed by microorganisms while stabilizing or degrading nitrogenous compounds under aerobic conditions over an extended time period.

NPDES Permit: An individual or general permit issued by the Mississippi Environmental Quality Permit Board pursuant to regulations adopted by the Mississippi Commission on Environmental Quality under Mississippi Code Annotated (as amended) §§ 49-17-17 and 49-17- 29 for discharges into state waters.

Photosynthesis: The biochemical synthesis of carbohydrate-based organic compounds from water and carbon dioxide using light energy in the presence of chlorophyll.

Point Source: Pollution loads discharged at a specific location from pipes, outfalls, and conveyance channels from either wastewater treatment plants or industrial waste treatment facilities. Point sources can also include pollutant loads contributed by tributaries to the main receiving stream.

Pollution: Contamination, or other alteration of the physical, chemical, or biological properties, of any waters of the state, including change in temperature, taste, color, turbidity, or odor of the waters, or such discharge of any liquid, gaseous, solid, radioactive, or other substance, or leaks into any waters of the state, unless in compliance with a valid permit issued by the Permit Board.

Publicly Owned Treatment Works (POTW): A waste treatment facility owned and/or operated by a public body or a privately owned treatment works, which accepts discharges, which would otherwise be subject to Federal Pretreatment Requirements.

Reaeration: The net flux of oxygen occurring from the atmosphere to a body of water across the water surface.

Regression Coefficient: An expression of the functional relationship between two correlated variables that is often empirically determined from data, and is used to predict values of one variable when given values of the other variable.

Respiration: The biochemical process by means of which cellular fuels are oxidized with the aid of oxygen to permit the release of energy required to sustain life. During respiration, oxygen is consumed and carbon dioxide is released.

Sediment Oxygen Demand: The solids discharged to a receiving water are partly organics, which upon settling to the bottom decompose aerobically, removing oxygen from the surrounding water column.

Storm Runoff: Rainfall that does not evaporate or infiltrate the ground because of impervious land surfaces or a soil infiltration rate slower than rainfall intensity, but instead flows into adjacent land or water bodies or is routed into a drain or sewer system.

Streeter-Phelps DO Sag Equation: An equation, which uses a mass balance approach to determine the DO concentration in a water body downstream of a point source discharge. The equation assumes that the stream flow is constant and that CBODu exertion is the only source of DO deficit while reaeration is the only sink of DO deficit.

Total Ultimate Biochemical Oxygen Demand: Also called TBODu, the amount of oxygen consumed by microorganisms while stabilizing or degrading carbonaceous or nitrogenous compounds under aerobic conditions over an extended time period.

Total Kjeldahl Nitrogen: Also called TKN, organic nitrogen plus ammonia nitrogen.

Total Maximum Daily Load or TMDL: The calculated maximum permissible pollutant loading to a water body at which water quality standards can be maintained.

Waste: Sewage, industrial wastes, oil field wastes, and all other liquid, gaseous, solid, radioactive, or other substances that may pollute or tend to pollute any waters of the State.

Waste load Allocation (WLA): The portion of a receiving waters loading capacity attributed to or assigned to point sources of a pollutant.

Water Quality Standards: The criteria and requirements set forth in State of Mississippi Water Quality Criteria for Intrastate, Interstate, and Coastal Waters. Water quality standards are standards composed of designated present and future most beneficial uses (classification of waters), the numerical and narrative criteria applied to the specific water uses or classification, and the Mississippi antidegradation policy.

Water Quality Criteria: Elements of state water quality standards, expressed as constituent concentrations, levels, or narrative statements, representing a quality of water that supports the present and future most beneficial uses.

Waters of the State: All waters within the jurisdiction of this state, including all streams, lakes, ponds, wetlands, impounding reservoirs, marshes, watercourses, waterways, wells, springs, irrigation systems, drainage systems, and all other bodies or accumulations of water, surface and underground, natural or artificial, situated wholly or partly within or bordering upon the state, and such coastal waters as are within the jurisdiction of the state, except lakes, ponds, or other surface waters which are wholly landlocked and privately owned, and which are not regulated under the Federal Clean Water Act (33 U.S.C.1251 et seq.).

Watershed: The area of land draining into a stream at a given location.

Abbreviations

BASINS.....................Better Assessment Science Integrating Point and Nonpoint Sources
BMP .... Best Management Practice
$CBOD_5$ .... 5-Day Carbonaceous Biochemical Oxygen Demand
$CBOD_U$... Carbonaceous Ultimate Biochemical Oxygen Demand
CWA .... Clean Water Act
DMR...Discharge Monitoring Report
US EPA ....U.S. Environmental Protection Agency
GIS ....Geographic Information System
HUC .... Hydrologic Unit Code
LA...Load Allocation
MARIS .... Mississippi Automated Resource Information System
MDEQ.. Mississippi Department of Environmental Quality
MGD.. Million Gallons per Day
MOS..Margin of Safety
$NBOD_U$... Nitrogenous Ultimate Biochemical Oxygen Demand
NH_3..Total Ammonia
NH_3-N.. Total Ammonia as Nitrogen
NO_2+ NO_3 ....Nitrite Plus Nitrate
NPDES ....National Pollutant Discharge Elimination System
RBA... Rapid Biological Assessment
7Q10.............7-Day Average Low Stream Flow with a 10-Year Occurrence Period
$TBOD_5$.. 5-Day Total Biochemical Oxygen Demand
$TBOD_u$ .... Total Ultimate Biochemical Oxygen Demand
TKN...Total Kjeldahl Nitrogen
TN...Total Nitrogen
TOC.. Total Organic Carbon
TP .... Total Phosphorus
USGS.. United States Geological Survey
WLA...Waste Load Allocation

APPENDIX A

Watershed Model and Siltation Analysis for Dump Lake Watershed

1.0 Model Selection

The Generalized Watershed Loading Function (GWLF) model was selected to estimate sediment and oxygen-demanding substance loadings to Dump Lake. Key characteristics of the GWLF model include:

- Limited data requirements
- Sediment simulation uses standard USLE method
- Hydrology simulation uses Curve Number method
- Capable of representing heterogeneous land uses

The sediment loads from all land uses except aquaculture (catfish ponds) were generated using the GWLF model for the Dump Lake watershed. The catfish pond sediment load was simulated outside of the GWLF model to account for pond management practices and seasonal variation in sediment concentrations. The GWLF model loads and catfish pond sediment loads were applied to a siltation and life span analysis for assessment of sediment/siltation impairments.

The nutrient load from all land uses except catfish ponds was generated using the GWLF model for the Dump Lake watershed. The catfish pond nutrient load was simulated outside of the GWLF model to account for pond management practices and seasonal variation in nutrient concentrations. The GWLF model loads and catfish pond nutrient loads were applied to CE-QUAL-W2, a separate receiving water model, for assessments of the organic enrichment/low dissolved oxygen (DO) and nutrient impairments.

2.0 Model Framework

The GWLF model, which was originally developed by Cornell University (Haith and Shoemaker, 1987; Haith et al., 1992), provides the ability to simulate runoff, sediment, and nutrient loadings from watersheds given variable-size source areas (e.g., agricultural, forested, and developed land). It also has algorithms for calculating septic system loads and allows for the inclusion of point source discharge data. GWLF is a continuous simulation model that uses daily time steps for weather data and water balance calculations. Monthly calculations are made for sediment and nutrient loads, based on daily water balance totals that are summed to give monthly values.

GWLF is an aggregate distributed/lumped parameter watershed model. For surface loading, it is distributed in the sense that it allows multiple land use/cover scenarios. Each area is assumed to be homogeneous with respect to various attributes considered by the model. Additionally, the model does not spatially distribute the source areas, but aggregates the loads from each area into a watershed total. In other words, there is no spatial routing. For subsurface loading, the model acts as a lumped parameter model using a water balance approach. No distinctly separate areas are considered for subsurface flow contributions. Daily water balances are computed for an unsaturated zone as well as for a saturated subsurface zone, where infiltration is computed as the difference between precipitation and snowmelt minus surface runoff and evapotranspiration.

GWLF models surface runoff using the Soil Conservation Service Curve Number (SCS-CN) approach with local daily weather (temperature and precipitation) inputs. Erosion and sediment yield are estimated using monthly erosion calculations based on the Universal Soil Loss Equation (USLE) algorithm (with monthly rainfall-runoff coefficients) and a monthly composite of KLSCP values for each source area (e.g., land cover/soil type combination). The KLSCP factors are variables used in the calculations to depict changes in soil loss/erosion (K), the length/slope factor (LS), the vegetation cover factor (C), and the conservation practices factor (P). The USLE approach is commonly used to predict erosion, particularly in agricultural areas. The approach is a component of other watershed models such as the Agricultural Non Point Source Loading model (AGNPS) and the Soil and Water Assessment Tool (SWAT). A sediment delivery ratio (SDR), based on watershed size, and a transport capacity based on average daily runoff are applied to the calculated erosion to determine sediment yield for each source area.

Surface nutrient losses are determined by applying dissolved nitrogen and dissolved phosphorus coefficients to surface runoff and a sediment coefficient to the yield portion for each agricultural source area. Point source discharges, which are not of concern in this study area, can also contribute to dissolved loads to the stream and are specified in terms of kilograms per month. Manured areas, as well as septic systems, can be considered. Urban nutrient inputs are all assumed to be solid-phase, and the model uses an exponential accumulation and washoff function for these loadings. Subsurface losses are calculated using dissolved nitrogen and dissolved phosphorus coefficients for shallow groundwater contributions to stream nutrient loads. The subsurface submodel considers only a single, lumped-parameter contributing area.

Evapotranspiration is determined using daily weather data and a cover factor dependent on land use/cover type. A water balance is performed daily using supplied or computed precipitation, snowmelt, initial unsaturated zone storage, maximum available zone storage, and evapotranspiration values. All of the equations used by the model can be found in the original GWLF paper (Haith and Shoemaker, 1987) and GWLF User's Manual (Haith et al., 1992).

3.0 Model Configuration

Watershed data needed to run the GWLF model with the BasinSim 1.0 interface were generated using geographic information systems (GIS) spatial coverages, local weather data, literature values, and other information. The BasinSim 1.0 watershed simulation program is a windows-based modeling system that facilitates the development of model input data and provides additional functionality (Dai et al, 2000). BasinSim 1.0 integrates a graphic Windows interface, extensive databases (land uses, population, soils, water discharge, water quality, climate, point nutrient sources, etc.), and the GWLF model (with modifications) into a single software package. The GWLF model in

BasinSim 1.0 requires the user to construct three input files for the simulation of both watershed hydrology and nutrient loading: a transport file, a nutrient file and a weather file. The watershed was divided into six drainage areas and each drainage area was modeled separately (Figure 1). Tributaries 1, 2, and 3 drain significant areas of steeply sloping forested upland areas. Dump Lake inlet, direct drainage area, and tributary 4 are confined to the flat agricultural land characteristic of the Mississippi River floodplain.

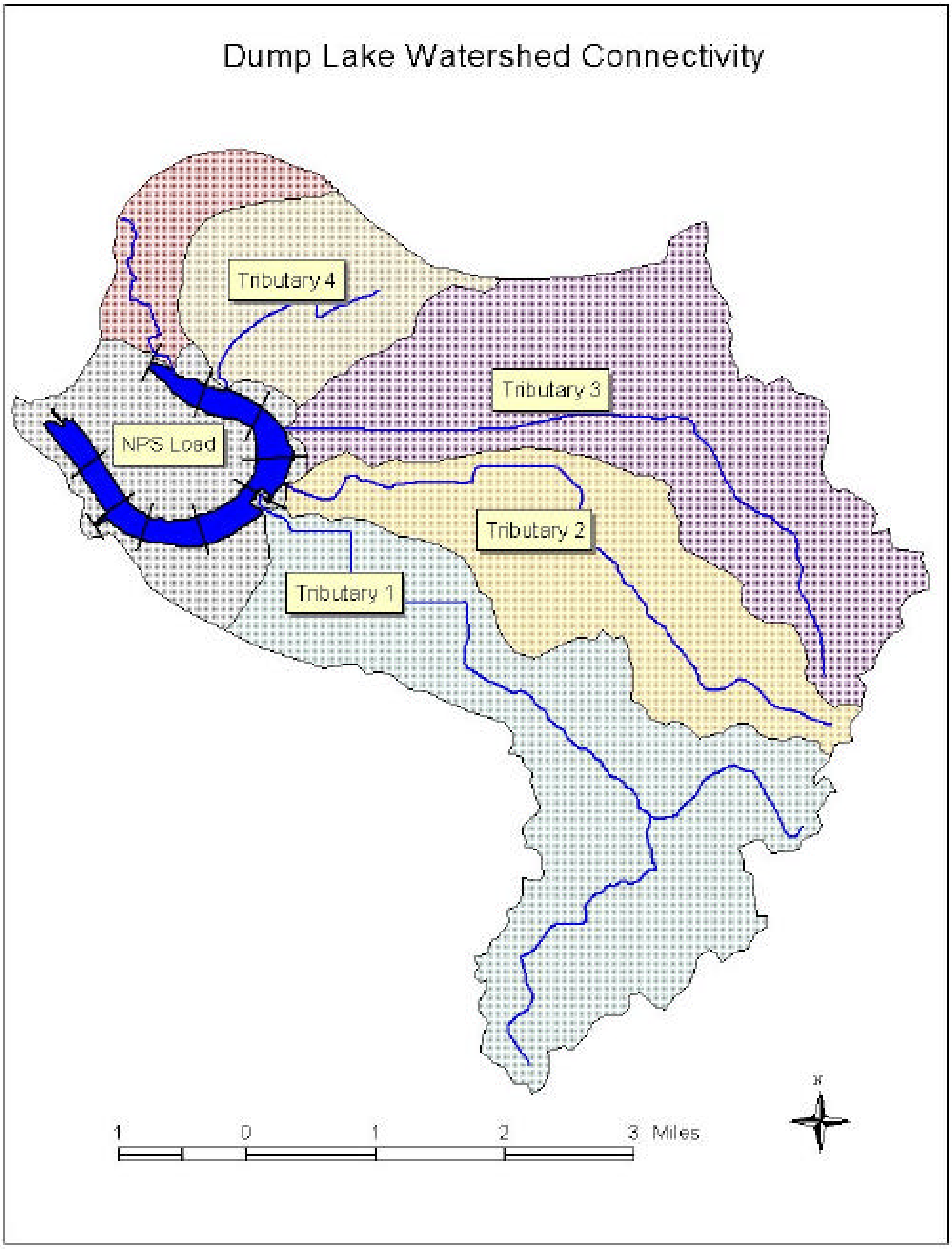

Figure A-1. Dump Lake Watershed Connectivity

For execution, the model requires three separate input files containing transport parameters, nutrient parameters, and weather-related data. More detailed information about these parameters and other secondary parameters can be obtained from the GWLF User's Manual (Haith et al., 1992). Pages 15 through 41 of the manual provide specific details that describe equations and typical parameter values used in the model.

3.1 Transport Parameters

The transport file (TRANSPRT.DAT) defines parameters that are a function of hydrology, erosion, and sedimentation. These parameters include global transport parameters, seasonal transport parameters, and source area transport parameters.

3.1.1 Source Area Transport Parameters

Model inputs for the source area transport parameters are shown in Figures A-2, A-3, and A-4. These parameters account for spatial variation in hydrology, erosion, and sedimentation. They include land use area, curve number, and the Universal Soil Loss (USLE) parameters K, LS, C, and P.

Direct Drainage Area				Tributary 1			
Land Use Type	Area (ha)	CN	K*LS*C*P	Land Use Type	Area (ha)	CN	K*LS*C*P
Corn	23.2	82	0.0364	Corn	41.2	83	0.0330
Cotton	277.6	82	0.0516	Cotton	219.7	84	0.0230
Other Small Grains	5.4	80	0.0644	Other Small Grains	1.0	80	0.0189
Pasture/Range	130.0	74	0.0060	Pasture/Range	185.5	76	0.0272
Rice	7.8	80	0.0109	Rice	2.0	83	0.0088
Snap Beans	5.8	80	0.0247	Snap Beans	0.8	82	0.0237
Sorghum	8.0	82	0.0204	Sorghum	1.8	85	0.0183
Soybeans	16.5	82	0.0517	Soybeans	7.4	85	0.0214
Winter Wheat	7.2	80	0.0089	Winter Wheat	2.0	83	0.0079
Aquaculture	0.0			Aquaculture	0.0		
Bottomland Hardwood	9.8	70	0.0010	Bottomland Hardwood	31.9	77	0.0001
Deciduous Forest	0.0			Deciduous Forest	1119.4	55	0.0160
Freshwater	31.0	100	0.0000	Freshwater	1.8	100	0.0000
Mixed Forest	0.0			Mixed Forest	0.5	55	0.0002
Upland Scrub/Shrub	5.1	70	0.0001	Upland Scrub/Shrub	113.4	56	0.0060
Woods	3.8	70	0.0005	Woods	17.5	66	0.0026
Urban Pervious	1.5	79	0.0044	Urban Pervious	2.7	77	0.0047
Urban Impervious	0.2	98	0.0000	Urban Impervious	0.3	98	0.0000

Figure A-2. Land Use Parameters for the Direct Drainage Area and Tributary 1

Tributary 2

Land Use Type	Area (ha)	CN	K*LS*C*P
Corn	12.6	85	0.0443
Cotton	149.9	84	0.0263
Other Small Grains	1.7	83	0.0595
Pasture/Range	152.4	77	0.0267
Rice	1.7	83	0.0164
Snap Beans	2.1	83	0.1942
Sorghum	3.6	84	0.0229
Soybeans	7.3	84	0.0222
Winter Wheat	1.5	83	0.0058
Aquaculture	0.0		
Bottomland Hardwood	71.1	75	0.0013
Deciduous Forest	446.3	55	0.0146
Freshwater	7.2	100	0.0000
Mixed Forest	40.9	60	0.0001
Upland Scrub/Shrub	90.6	60	0.0096
Woods	39.4	66	0.0026
Urban Pervious	2.7	80	0.0044
Urban Impervious	0.3	98	0.0000

Tributary 3

Land Use Type	Area (ha)	CN	K*LS*C*P
Corn	111.5	84	0.0301
Cotton	127.3	84	0.0598
Other Small Grains	2.8	83	0.0192
Pasture/Range	325.5	81	0.0185
Rice	3.1	84	0.0091
Snap Beans	3.8	83	0.0447
Sorghum	22.0	84	0.0411
Soybeans	24.9	85	0.0260
Winter Wheat	5.6	84	0.0095
Aquaculture	15.3	100	0.0000
Bottomland Hardwood	140.4	76	0.0003
Deciduous Forest	655.8	56	0.0095
Freshwater	14.8	100	0.0000
Mixed Forest	38.5	67	0.0095
Upland Scrub/Shrub	56.9	77	0.0005
Woods	46.0	71	0.0067
Urban Pervious	6.1	79	0.0044
Urban Impervious	0.7	98	0.0000

Figure A-3. Land Use Parameters for Tributary 2 and Tributary 3

Tributary 4

Land Use Type	Area (ha)	CN	K*LS*C*P
Corn	68.1	85	0.0473
Cotton	218.5	84	0.0561
Other Small Grains	1.3	81	0.0086
Pasture/Range	133.0	83	0.0137
Rice	2.2	83	0.0093
Snap Beans	1.0	82	0.2072
Sorghum	2.5	84	0.0201
Soybeans	21.5	84	0.0530
Winter Wheat	2.6	83	0.0078
Aquaculture	0.0		
Bottomland Hardwood	65.4	74	0.0004
Deciduous Forest	0.0		
Freshwater	1.4	100	0.0000
Mixed Forest	0.0		
Upland Scrub/Shrub	21.6	75	0.0001
Woods	7.3	77	0.0008
Urban Pervious	1.1	83	0.0114
Urban Impervious	0.1	98	0.0000

Tributary 5

Land Use Type	Area (ha)	CN	K*LS*C*P
Corn	11.0	82	0.0521
Cotton	153.0	83	0.0659
Other Small Grains	1.1	80	0.2727
Pasture/Range	48.9	75	0.0220
Rice	1.3	80	0.0109
Snap Beans	1.2	80	0.0246
Sorghum	1.3	82	0.0796
Soybeans	2.6	82	0.0638
Winter Wheat	1.2	80	0.0088
Aquaculture	0.0		
Bottomland Hardwood	34.7	71	0.0006
Deciduous Forest	0.0		
Freshwater	4.4	100	0.0000
Mixed Forest	0.0		
Upland Scrub/Shrub	3.3	70	0.0002
Woods	8.7	72	0.0002
Urban Pervious	1.0	79	0.0215
Urban Impervious	0.1	98	0.0000

Figure A-4. Land Use Parameters for Tributary 4 and Tributary 5

The watershed boundary was delineated using a 10-meter Digital Elevation Map (DEM) and U.S. Geological Survey (USGS) 7.5 minute digital topographic maps (24K DRG – Digital Raster Graphics). The land use and land cover percentages were derived from a data layer developed as part of the Mississippi Land Cover Project (MDEQ, 1997) and the 2001 cropland data layer developed by the National Agricultural Statistics Service

(USDA, 2001). The nine land uses used for model simulation were grouped into five categories for model result presentation (Table A-1).

Table A-1. Land Use Categories

Category	Land Use/Land Cover	Area (ha)	Area (% of Total)
Cultivated Agriculture	Cotton, Corn, Soybean, Sorghum, Snap Beans, Other Small Grains, Rice, Winter Wheat, Sunflower	1599	27.9
Noncultivated Agriculture	Pasture, Range, Fallow	975	17.0
Catfish Ponds	Catfish Ponds	15	0.3
Residential	Pervious Residential, Impervious Residential	17	0.3
Other*	Bottomland Hardwood Forest, Riverine Swamp, Upland Scrub, Woods, Freshwater Scrub, Open Water	3117	54.5

*This excludes the 166.9 hectare Dump Lake surface area.

The curve number parameter determines the amount of precipitation that infiltrates into the ground or enters surface water as runoff. It is based on specified combinations of land use/cover and hydrologic soil type and is calculated directly using digital land use and soils coverages. Soils data were obtained from Mississippi county soil surveys and the State Soil Geographic (STATSGO) database, as developed by the Natural Resources Conservation Services (NRCS).

The USLE equation determines soil erodibility based on the K-factor, LS-factor, C-factor, and P-factor. Unless otherwise specified, these parameters are derived from the NRCS Natural Resources Inventory (NRI) database (1992). The individual parameters are described below.

- *K factor:* This relates to inherent soil erodibility and affects the amount of soil erosion taking place on a given unit of land. K-factor values were derived from STATSGO for each soil type and assigned to land use areas based on the distribution of soils within that land use area.

- *LS factor:* This is a function of the length and grade of the slope from a source area to the waterbody. The average slope was calculated for each land use area based on the 10 meter DEM coverage. The slope length was derived from regional crop specific literature values from the NRCS NRI database (1992).

- *C factor:* This is related to the amount of vegetative cover in an area and is largely controlled by the crops grown and the cultivation practices used. Values range from 0 to 1.0, with larger values indicating a lower potential for erosion. The C factor was derived from crop-specific literature values from the NRCS NRI database (1992) based on moderate tillage practices.

- *P factor:* This is directly related to the conservation practices used in agricultural areas. Values range from 0 to 1.0, with larger values indicating a lower potential for erosion.

3.1.2 Seasonal Transport Parameters

Model inputs for the seasonal transport parameters are shown in Figure A-5. These parameters account for seasonal variability in hydrology, erosion, and sedimentation. The monthly evapotranspiration cover coefficient, day length, and erosivity coefficient are based on regional literature values. (Haith et al., 1992).

Month	ET Cover Coef.	Day Length (hrs)	Growing Season	Erosivity Coef.
Apr	0.999	12.8	1	0.2
May	0.999	13.7	1	0.2
Jun	0.999	14.2	1	0.2
Jul	0.999	14	1	0.2
Aug	0.999	13.2	1	0.2
Sep	0.999	12.2	1	0.2
Oct	0.999	11.2	1	0.2
Nov	0.700	10.2	0	0.11
Dec	0.700	9.8	0	0.11
Jan	0.700	10	0	0.11
Feb	0.700	10.8	0	0.11
Mar	0.700	11.8	0	0.11

Figure A-5. Seasonal Transport Parameters

3.1.3 Global Transport Parameters

Model inputs for the global parameters are shown in Figures A-6 and A-7. Critical global parameters include the unsaturated water capacity, seepage coefficient, recession coefficient, and SDR. The unsaturated water capacity is a function of the maximum watershed rooting depth and the soil available water storage capacity. The seepage coefficient is a function of the loss of water to the deep aquifer. The recession coefficient is a function of the basin's hydrologic response to a precipitation event. SDR specifies the percentage of eroded sediment delivered to surface water and is empirically based on watershed size. These parameters were set within reasonable ranges to match basin characteristics.

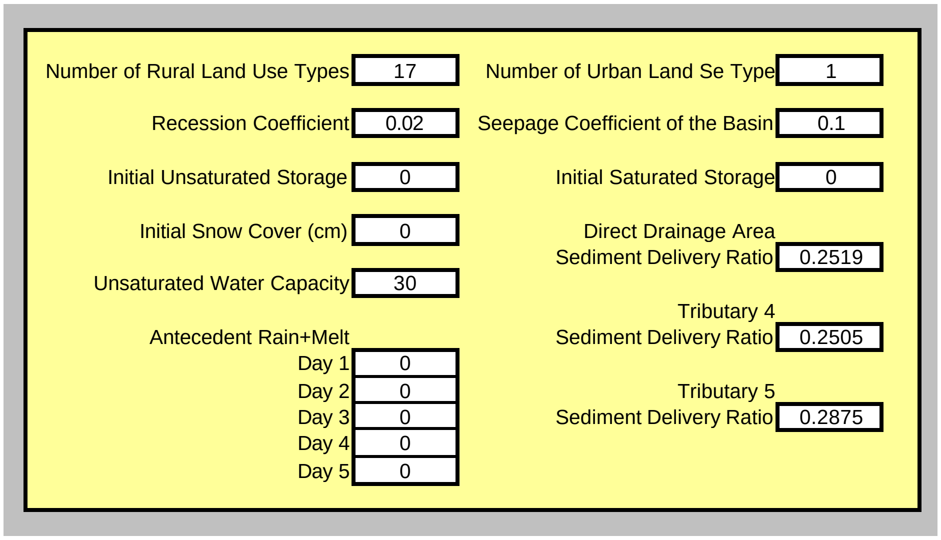

Figure A-6. Global Transport Parameters for the Direct Drainage Area and Tributaries 4 and 5

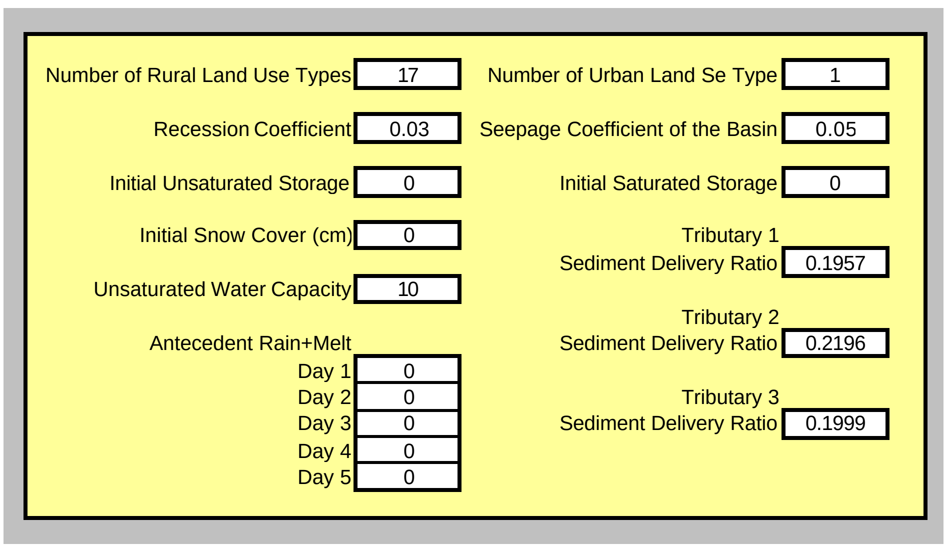

Figure A-7. Global Transport Parameters for Tributaries 1, 2 and 3

3.2 Nutrient Parameters

The nutrient file (NUTRIENT.DAT) specifies the loading parameters for the different sources. The dissolved concentrations for each land use are derived from the literature values for fallow, corn, and small grains and are shown in Figure A-8 (Haith et al., 1992). Soil nitrogen and phosphorus concentrations of 1000 mg/kg and 880 mg/kg, respectively, and groundwater nitrogen and phosphorus concentrations of 1.08 mg/L and 0.029 mg/L, respectively, were also determined using regional literature values (Haith et al., 1992).

No. of Rural Land Uses: 17

Land Use	N mg/l	P mg/l
Corn	2.90	0.26
Cotton	2.90	0.26
Other Small Grains	1.80	0.30
Pasture/Range/Non-Agriculture	1.80	0.30
Rice	1.80	0.30
Snap Beans	2.90	0.26
Sorghum	1.80	0.30
Soybeans	2.90	0.26
Winter Wheat	1.80	0.30
Aquaculture	2.60	0.10
Bottomland Hardwood Forest	2.00	0.30
Deciduous Forest	1.00	0.13
Freshwater	0.00	0.00
Mixed Forest	1.00	0.13
Upland Scrub/Shrub	1.00	0.13
Woods	1.00	0.13
Urban Pervious	1.00	0.13
Urban Impervious	3.00	0.25

Figure A-8. Dissolved Nitrogen and Phosphorus Concentrations

3.3 Weather Data

The weather file (WEATHER .DAT) contains daily average temperature and total precipitation values for each year simulated. Daily precipitation and temperature data were obtained from local National Climatic Data Center (NCDC) weather stations and are shown in Table A-2 and Figure A-9. The period of record selected for model runs, April 1, 1990 through March 31, 2000, was based on the availability of daily precipitation and temperature data.

Table A-2. Weather Stations

Weather Station	Station Code	Data Type	Data Period
Yazoo City 5 NNE	MS9860	Daily Precipitation	1960-2000
Jackson International Airport	WBAN 03940	Daily Max/Min Temp	1963-2000

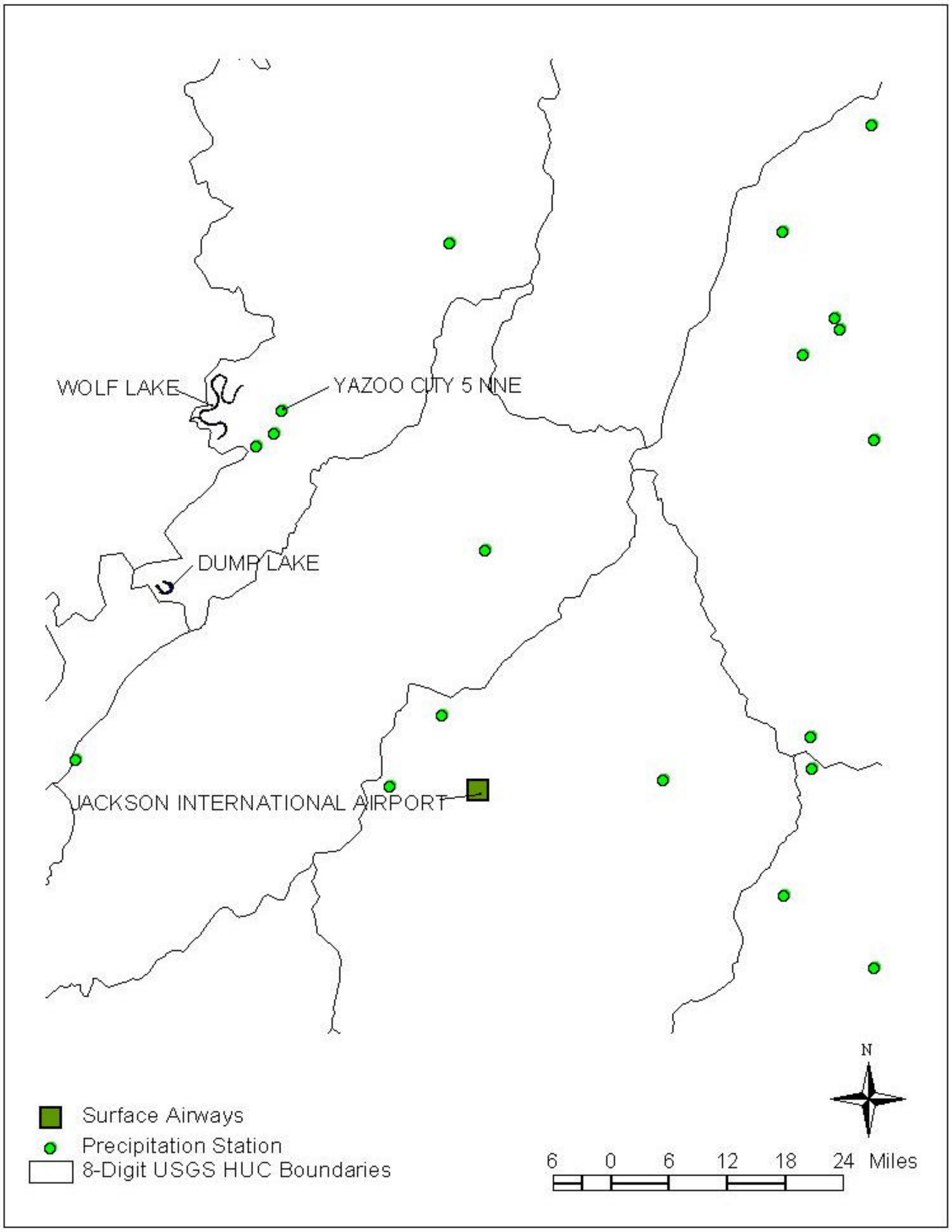

Figure A-9. Precipitation and Temperature Gage Locations

4.0 Watershed Model Calibration

The GWLF model was not calibrated to actual observations, since sufficient data were not available. However, local land use, soil, and meteorological data were used to define model parameters and ensure appropriateness in load estimation. Land management practices including reduced tillage, cover crops, and detention ponds are widely used in the Mississippi Delta (Yuan and Bingner, 2002). Therefore, cover factors used in the USLE method were based on moderate tillage.

5.0 Catfish Pond Analysis

Catfish ponds, representing 38 acres or less than 1 percent of the total watershed area, were simulated outside of GWLF to account for pond management practices and seasonal variations in sediment and nutrient concentrations. Sediment, total nitrogen, and total phosphorus loads were simulated using a spreadsheet tool based on the method described in Tucker et al., 1996. Critical assumptions regarding pond management practices in the Yazoo River Basin incorporated into this analysis include

- Pond surface level is maintained between 7.5 and 15 centimeters below top of drain.
- Food fish ponds represent 90 percent of the total catfish pond area, and one sixth of the food fish ponds are drained annually throughout the year.
- Fingerling ponds represent 10 percent of the total catfish pond area, and all of the fingerling ponds are drained annually between December and April.
- Broodfish ponds represent a negligible percent of the total catfish pond area.

Catfish pond overflows were predicted from January 1997 to December 2000 on a daily time step based on assumed pond level management practices and daily precipitation, evaporation, and infiltration. The overflow was calculated using the following equation from Tucker et al. 1996, and is shown in Figure A-10.

$$\mathbf{O_d = L_{d-1} - L_d - P_d - 0.8 * E_d - I + GW_d}$$

Where

O_d = Overflow (cm) on day d
L_{d-1} = Pond Water Level (cm) at end of day d-1
L_d = Pond Water Level (cm) at end of day d
P_d = Precipitation (cm) on day d
E_d = Pan Evaporation on day d
I = Daily infiltration loss (0.04 cm)
GW_d = Groundwater pumped into pond (cm) on day d

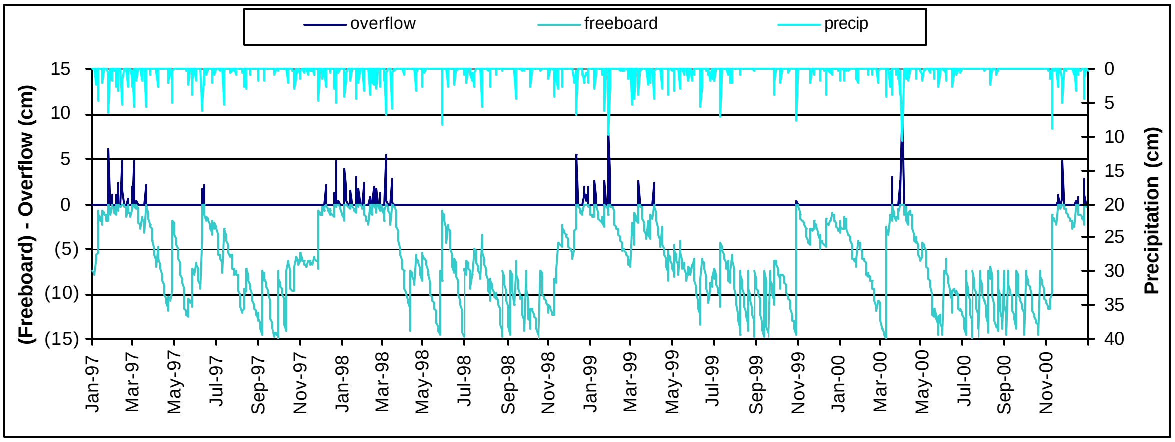

Figure A-10. Predicted Daily Catfish Pond Overflows Jan 1997–Dec 2000

Pond sediment and nutrient loads are predicted on a monthly time step based on average seasonal concentrations, daily overflow water balance totals summed to monthly values, and pond drainage volume assumptions. The predicted seasonal nonvolatile suspended sediment (NVSS), and particulate and soluble phosphorus and nitrogen are shown in Table A-3. NVSS was estimated to be 70 percent of the total suspended solids (C. Tucker, 2003).

Table A-3: Seasonal NVSS, Total Phosphorus (TP), and Total Nitrogen (TN) Concentrations

Season	NVSS (mg/L)	TP (particulate) (mg/L)	TP (soluble) (mg/L)	TN (particulate) (mg/L)	TN (soluble) (mg/L)
Spring	92	0.33	0.02	3.00	1.84
Summer	87	0.47	0.06	5.95	1.17
Autumn	61	0.29	0.02	3.31	3.23
Winter	72	0.33	0.01	3.55	1.76
Mean	78	0.35	0.03	3.95	2.00

Source: Tucker et al, 1996.

The predicted monthly sediment and nutrient loads from January 1997 to December 2000 are shown in Figures A-11 to A-14. The predicted average annual loads from catfish ponds are 1.0 ton sediment, 0.26 ton nitrogen, and 0.01 ton phosphorus. Sediment, nitrogen and phosphorus loads were highest in the winter months, between November and March, when the highest precipitation occurred and the fingerling ponds were drained. Overflow discharges rarely occurred outside of the winter months.

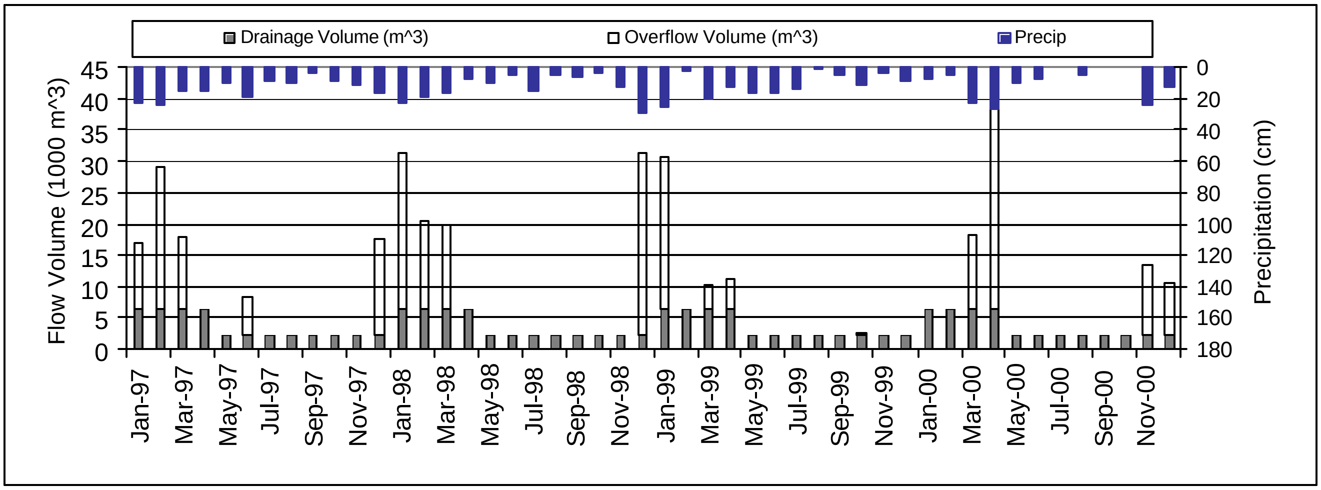

Figure A-11. Monthly Precipitation and Catfish Pond Overflow and Drainage

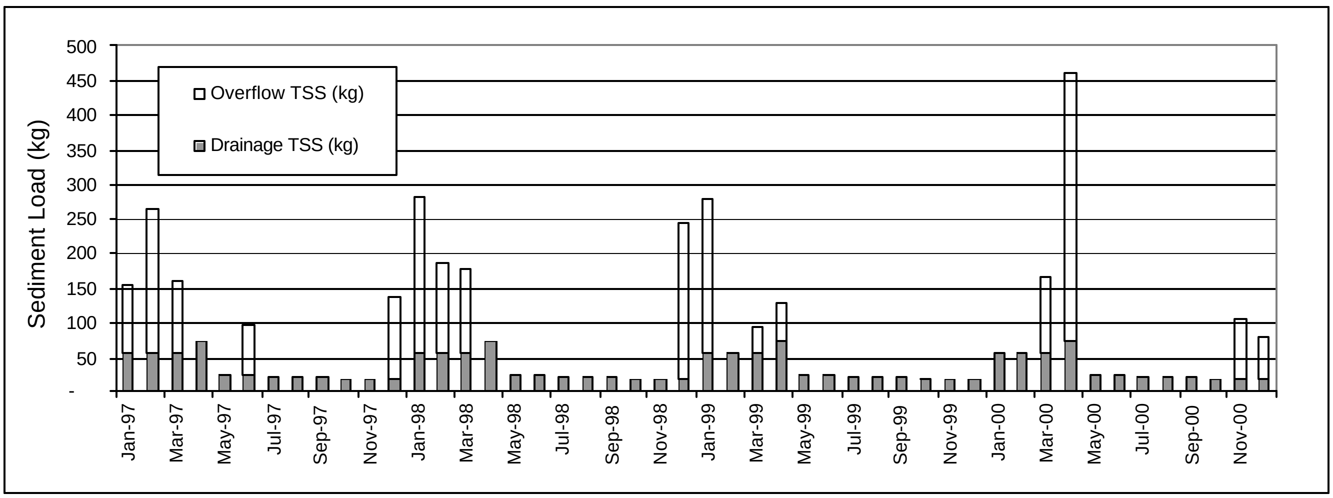

Figure A-12. Monthly Catfish Pond Overflow and Drainage Sediment Load

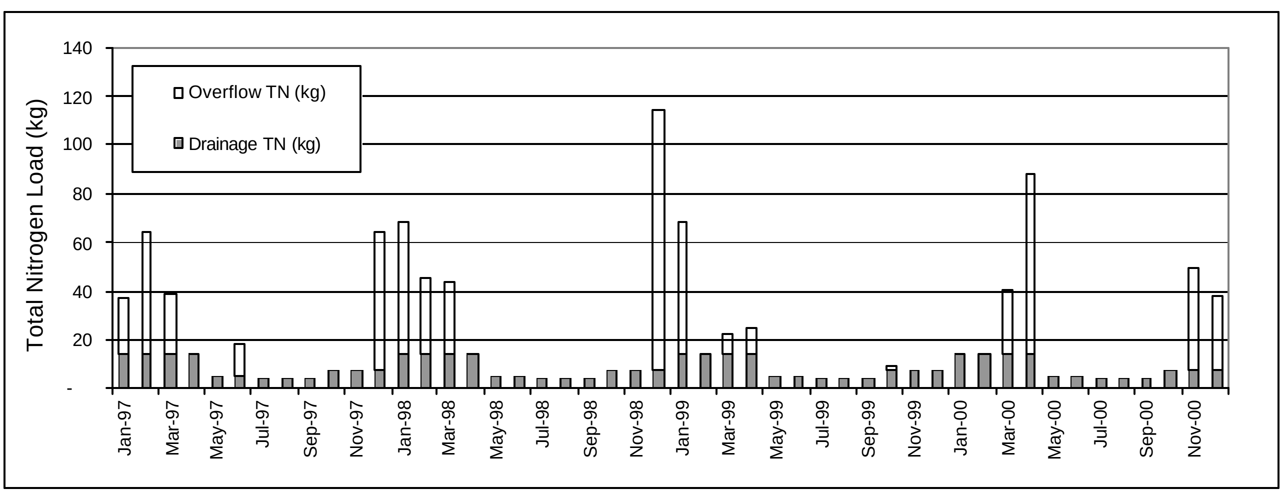

Figure A-13. Monthly Catfish Pond Overflow and Drainage Nitrogen Load

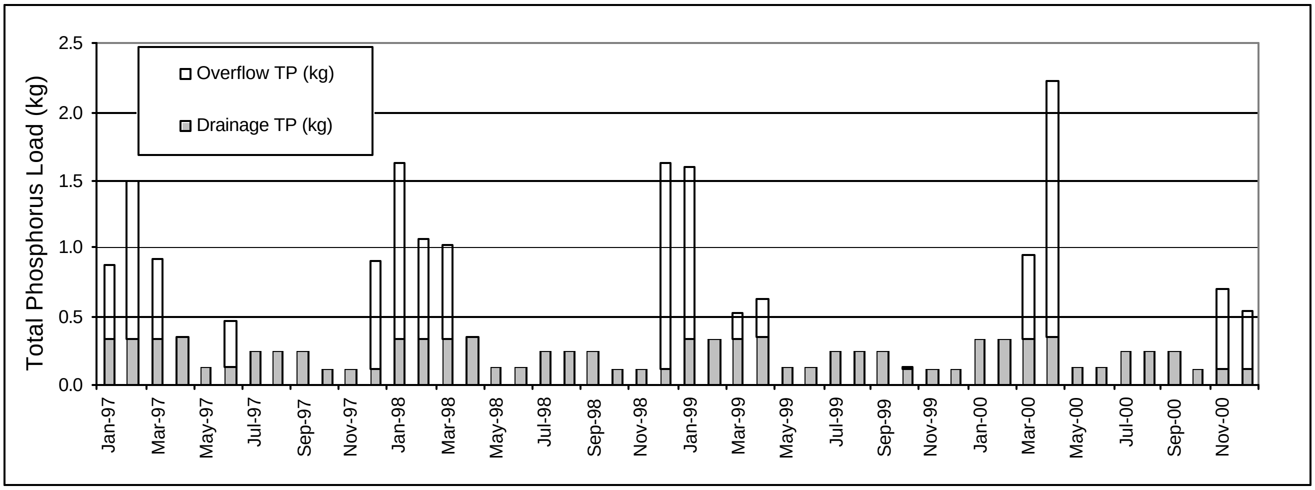

Figure A-14. Monthly Catfish Pond Overflow and Drainage Phosphorus Load

6.0 GWLF Model Results

The GWLF model was run for a 10-year period from April 1, 1990 to March 31, 1999. The first year of the model run was excluded because the GWLF model takes approximately 1 year to stabilize. The predicted annual sediment, nitrogen, and phosphorus loads for April 1991 to March 1999 are shown in Figures A-15 to A-17. The peak load generally follows the annual precipitation pattern with the highest sediment, nitrogen, and phosphorus loads occurring in 1991.

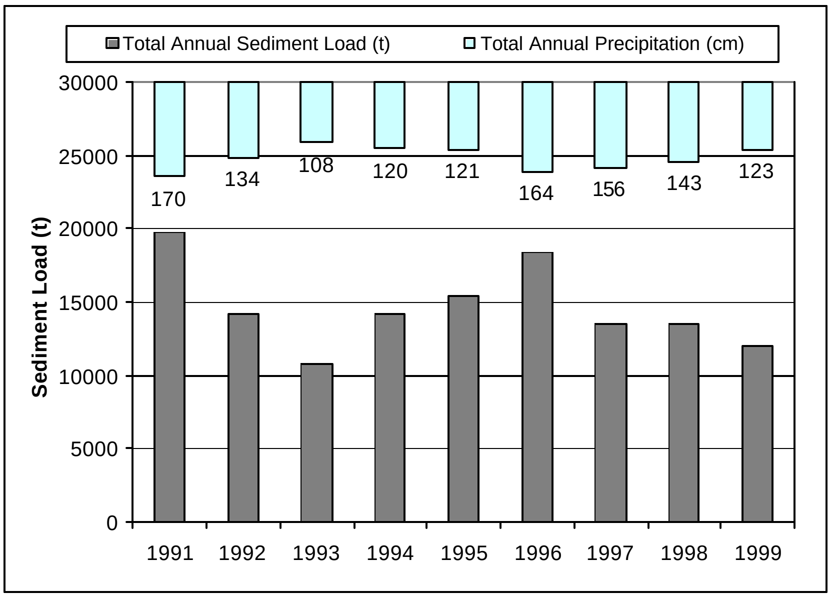

Figure A-15. Predicted Annual Sediment Load and Precipitation

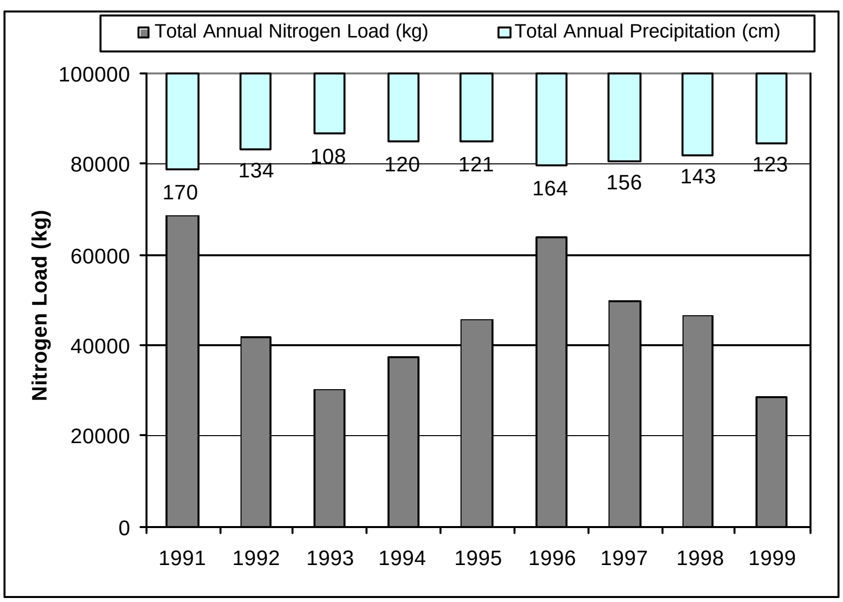

Figure A-16. Predicted Annual Nitrogen Load and Precipitation

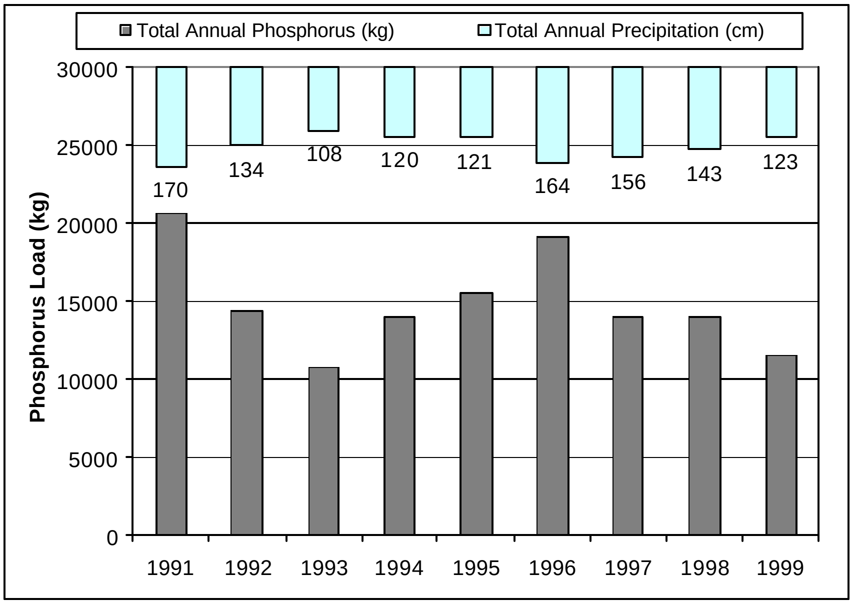

Figure A-17. Predicted Annual Phosphorus Load and Precipitation

The predicted average monthly sediment, nitrogen, and phosphorus loads are shown in Figures A-18 to A-20. These are the loads that actually reach the lake, and take into account the delivery ratio. The predicted load generally follows the monthly inflow pattern with the highest sediment, nitrogen, and phosphorus loads occurring in winter and early spring.

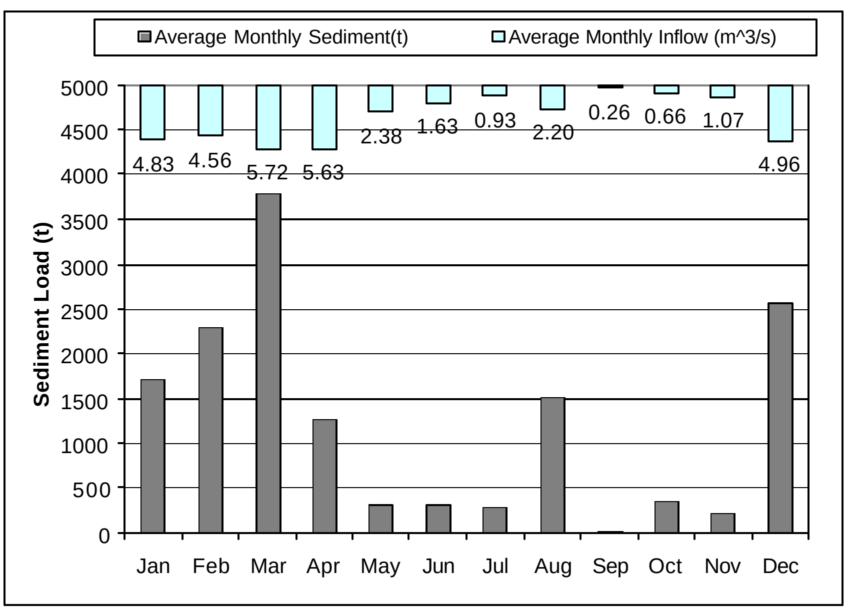

Figure A-18. Predicted Average Monthly Sediment Load and Inflow

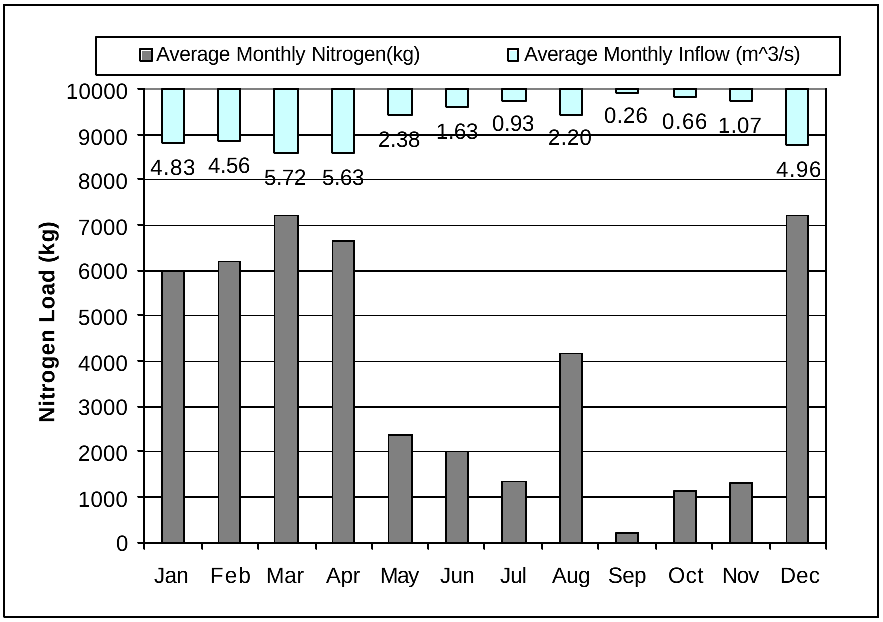

Figure A-19. Predicted Average Monthly Nitrogen Load and Inflow

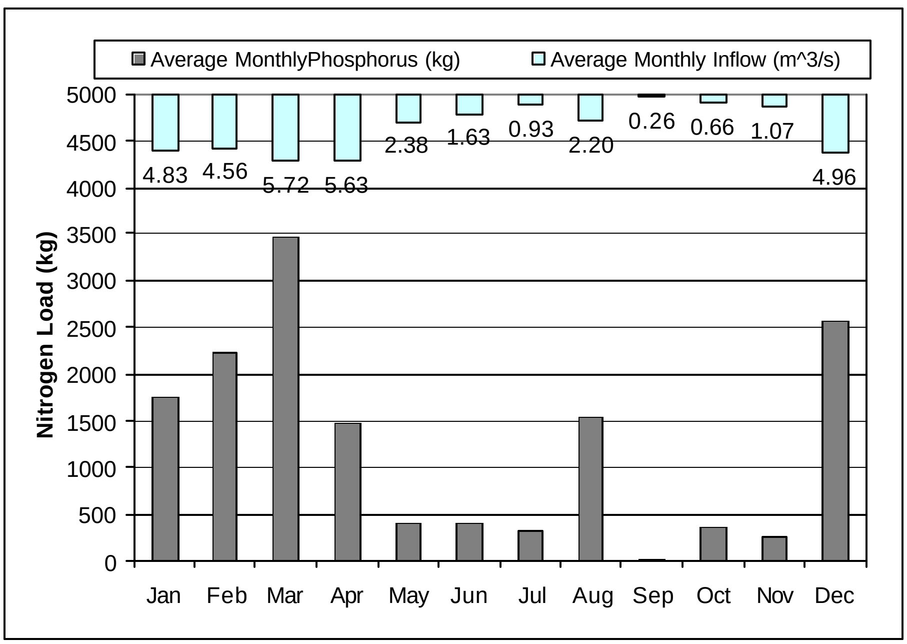

Figure A-20. Predicted Average Monthly Phosphorus Load and Inflow

7.0 Watershed Model Results

Sediment, total nitrogen, and total phosphorus loads by land use category are shown in Table A-4.

Table A-4. Predicted Average Annual Sediment, Nitrogen, and Phosphorus Loads

Land Use Category	Sediment Load (ton/year)	Total Nitrogen Load (ton/year)	Total Phosphorus Load (ton/year)
Cultivated Agriculture	8,891	20.53	8.90
Noncultivated Agriculture	2,147	7.78	2.11
Catfish Ponds	1	0.26	0.06
Residential	24	1.01	0.10
Other	3,583	5.99	3.47
Total	14,645	35.56	14.63

7.1 Siltation Rate/Estimated Life Span

The siltation rate in Dump Lake was assessed using the mean annual sediment load and the estimated trap efficiency. In addition, this analysis relies on two fundamental assumptions:

- Sediment accumulation occurs homogeneously over the entire lake area.
- Lake life span extends to approximately 50 percent of the lake surface area or 30 percent of the lake volume is reached. At this point the lake is considered "non-functioning."

Trap efficiency refers to the ability of lakes and reservoirs to retain a portion of the sediment loading. This efficiency is expressed as the percent of sediment retained compared to the total incoming sediment. The Brune method (USACE, 1989) is a widely used trap efficiency estimation method based on the ratio of waterbody volume to the annual inflow volume.

$$E = 100 * 97^{0.19^{\log(C/I)}}$$

where :

E = Trap Efficiency
C = Lake Capacity (Volume)
I = Inflow Volume

The two parameters required for the Brune Method are the Lake Capacity (Volume) and the annual inflow volume. The lake capacity is approximately 5.0 million cubic meters. The average annual inflow volume derived from GWLF model results is 19.9 million cubic meters. Based on this equation, the trap efficiency for Dump Lake is 92 percent. The predicted average sedimentation rate for the years 1991 to 1999 is 0.79 centimeters per year. The estimated life span based on the predicted sedimentation rate is 129 years.

Model Scenarios

The GWLF model was run for five additional scenarios to evaluate the effects of different land practices as well as the incorporation of wooded buffers. The goal of this analysis was to identify reasonable and achievable sedimentation rate targets while considering realistic land management and land use conversion options as well as long-term effects on the lake. However, the analysis does not make the attempt to include all of the possible changes in land use and land management. There are many other options available that have not been included in this report. This is because the models used in the development of this TMDL simulate land management practices as if they occur uniformly within an entire watershed. However, in a more realistic scenario, a variation of land management practices, with varying effectiveness, would be applied by individual landowners. Thus, this TMDL allows for flexibility in the allowable land management plans is necessary in order to develop and implement a practical implementation plan.

The selected scenarios are described in Table A-5. Table A-6 presents mean annual sediment load and mean annual siltation rate for existing conditions and the additional scenarios.

Table A-5. Existing Condition and Model Scenarios

	Scenario	Description
Existing	Moderate Tillage	The C factor in the USLE equation was adjusted to reflect moderate tillage practices on cultivated agricultural land.
Scenarios	Conventional Tillage	The C factor in the USLE equation was adjusted to reflect conventional tillage practices on cultivated agricultural land.
	50% Wooded and Moderate Tillage	The C factor in the USLE equation was adjusted to reflect moderate tillage practices on cultivated agricultural land. The wooded area was increased from 22% to 50% of the low land area and agricultural land was reduced from 75% to 48% of the lowland area.
	No Tillage	The C factor in the USLE equation was adjusted to reflect no tillage practices on cultivated agricultural land.
	50% Wooded and No Tillage	The C factor in the USLE equation was adjusted to reflect no tillage practices on cultivated agricultural land. The wooded area was increased from 22% to 50% of the low land area and agricultural land was reduced from 75% to 48% of the lowland area.
	100% Wooded	The low land wooded area was increased from 22% to 100% of the total low land area.

Table A-6. 1991-1999 Mean Annual Sediment Load

Scenario	Sediment Load (kton/yr)	Siltation Rate (cm/yr)
Conventional Tillage	19.43	1.05
Moderate Tillage (Baseline)	**14.65**	**0.79**
50% Wooded and Moderate Tillage	10.59	0.58
No Tillage	10.20	0.55
50% Wooded and No Tillage	6.23	0.34
100% Wooded	3.65	0.20

The siltation rates and estimated life spans for the existing conditions and additional scenarios are shown in Figures A-20 and A-21, respectively. The siltation rates and estimated life spans in this analysis are based on the conservative assumption that no compaction occurs in the deposited sediment and the specific weight of the sediment remains constant at 1 g/cm^3 (62 lbs/ft^3). It is expected that the actual siltation rates will be lower and estimated life span will be longer due to the compaction of the silt and clay factions of deposited sediment. Compaction occurs when sediment particles are slowly pressed together over time, reducing the pore space between them. Over extended periods compaction of silt and clay factions of sediment can increase the specific weight of the sediment and decrease the volume occupied by the sediment (Vanoni, 1975).

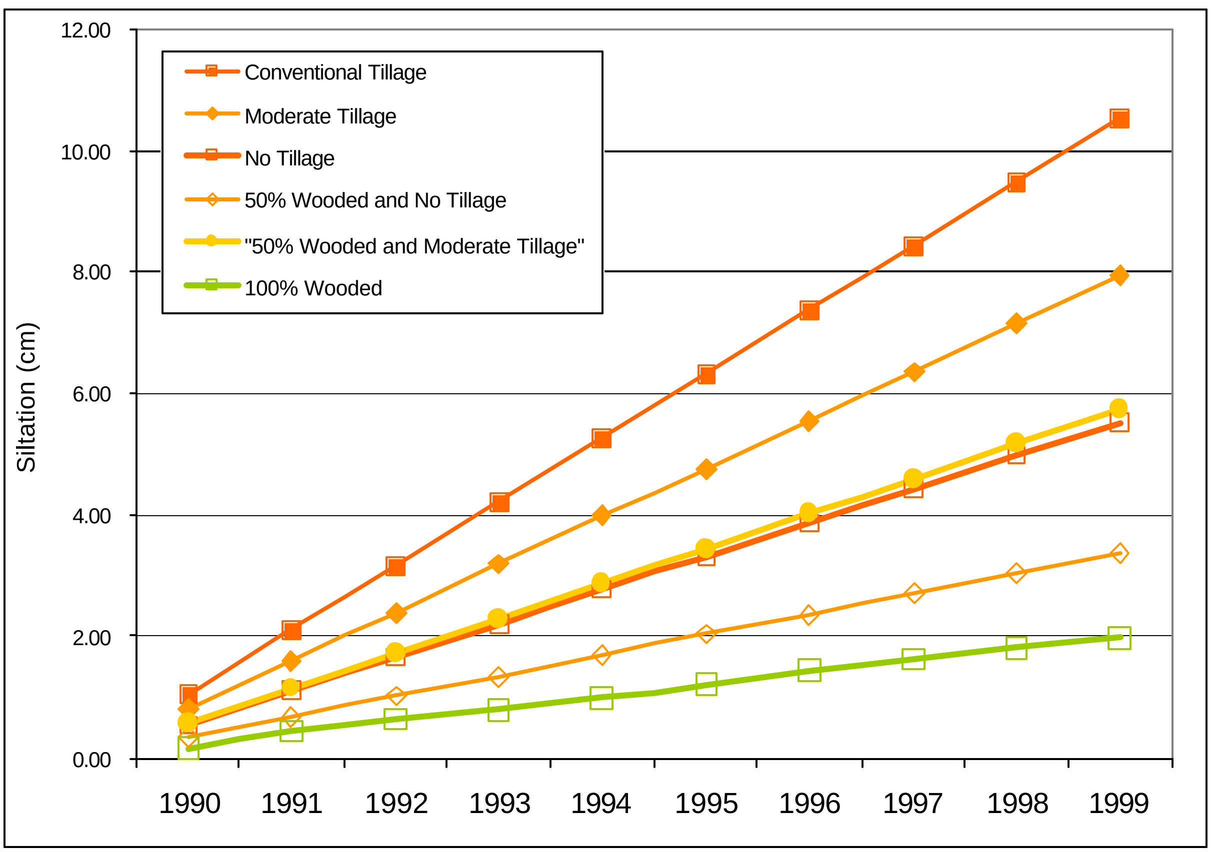

Figure A-20. Inlake Siltation Existing Conditions and Modeling Scenarios

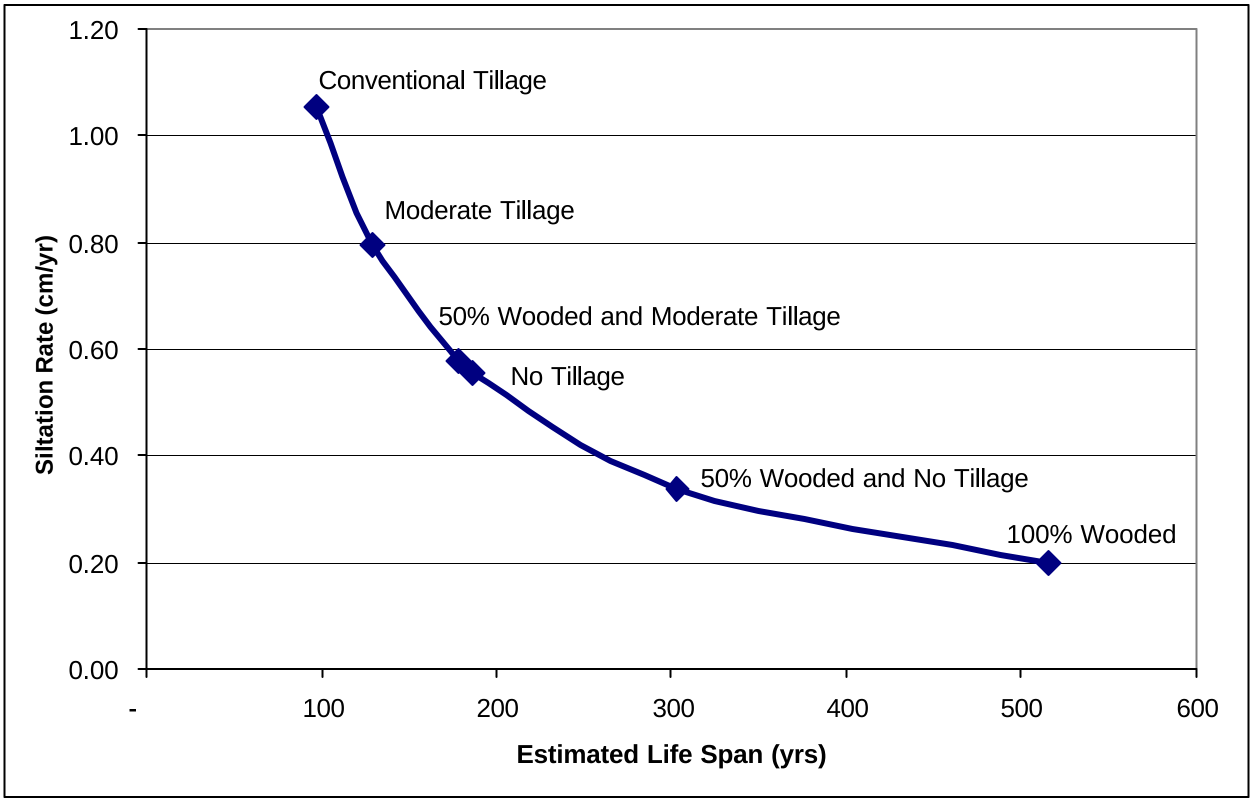

Figure A-21. Estimated Life span for Scenarios

After the results of each of these scenarios were reviewed, Mississippi Department of Environmental Quality (MDEQ) determined that the TMDL should be based on a range of siltation rates, reflecting the land management practices that could reasonably be put in place in the Dump Lake watershed. The upper limit of the siltation rate was set to reflect the land management scenario in which some of the agricultural land is returned to wooded areas, so that 50 percent of the total watershed is wooded. The remaining agricultural areas would continue to be cultivated using the moderate tillage practices that are currently in place. Thus, the upper limit of the siltation rate in Dump Lake is 0.58 cm/year. The lower limit of the siltation rate was set based on the most conservative landuse management practices that would be practicable for the Dump Lake watershed. The most conservative practices were determined to be the scenario in which some of the agricultural land is returned to wooded areas, so that 50 percent of the total watershed is wooded. The remaining agricultural areas would be cultivated so that no tillage was done in the watershed. Thus, the lower limit of the siltation rate in Dump Lake is 0.34 cm/year.

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APPENDIX B

Dump Lake Water Quality Model

1.0 Development of the Water Quality Model for the Dump Lake

Dump Lake is an oxbow lake formed on an abandoned arm of the Yazoo River. It is approximately 3.5 miles long and about 0.18 miles wide. The current Mississippi Department of Environmental Quality (MDEQ) water quality standard requires meeting a daily average and daily minimum dissolved oxygen (DO) criteria, as no nutrient criteria currently exists. Due to these technical and regulatory considerations, the CE-QUAL-W2 (W2) hydrodynamic and water quality model (Cole and Buchak, 1995) was used to simulate eutrophication processes within the lake. Inlake conditions are currently unknown.

2.0 Model Framework

The U.S. Army Corps of Engineers W2 model was selected as the receiving water model for simulating the eutrophication processes in Dump Lake. W2 is a two-dimensional, longitudinal/vertical (laterally averaged), hydrodynamic and water quality model. The model allows application to multiple branches for geometrically complex waterbodies (dendritic/branching lakes and reservoirs) with variable grid spacing, time-variable boundary conditions, and multiple inflows and outflows from point/nonpoint sources and precipitation.

The two major components of the W2 model are hydrodynamics and water quality kinetics. Both of these components are coupled, i.e., the hydrodynamic output is used to drive the water quality at every time step. The hydrodynamic portion of the model predicts water surface elevations, velocities, and temperature. The water quality portion can simulate 21 constituents including DO, nutrients, and phytoplankton interactions. Any combination of constituents can be simulated. Refer to document *CE-QUAL-W2: A Two-Dimensional Laterally Averaged, Hydrodynamic and Water Quality Model, Version 2.0 – Users Manual (EL-95)* for a more detailed discussion of simulated processes and model parameters.

3.0 Model Configuration

Model configuration involved setting up the model computational grid (bathymetry) based on information provided by MDEQ, and setting initial conditions, boundary conditions, and hydraulic and kinetic parameters for the hydrodynamic and water quality simulations. This section describes the configuration and key components of the model.

3.1 Segmentation/Computational Grid Setup

The computational grid setup defines the process of representing Dump Lake in the finite difference scheme. Dump Lake consists of a main branch and a branch feeding into it (Figure B-1). The model requires the user to set up the bathymetry file for each branch defining the upstream and downstream segments. The surface widths for each segment were derived from U.S. Geological Survey (USGS) quad maps. The spot elevation data provided by MDEQ at various transects along the lake was used to generate the bathymetry. The model was configured using two branches that were more finely defined by segments. The model was configured with 10 longitudinal segments, each with lengths ranging from 250 to 800 meters long, and contains up to a maximum of three 1-meter-thick vertical layers. Branch 1 consists of 8 segments and Branch 2 consists of 2 segments. Longitudinal and vertically varying cell widths ranged from 415 meters at the surface to 15 meters at the bottom.

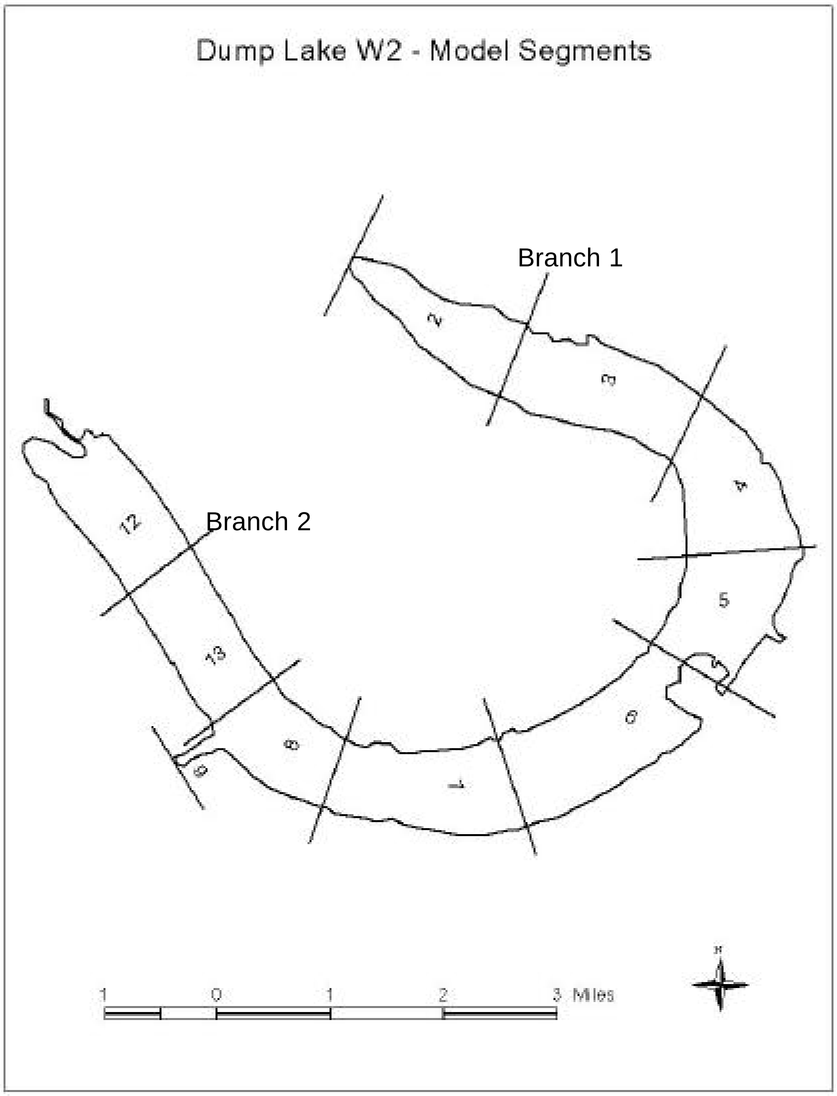

Figure B-1. Dump Lake segmentation

3.2 Initial Conditions

The W2 model requires specifying initial conditions in the control and bathymetry input files. The control file specifies the initial temperature and constituents (ammonia, nitrate-nitrite, organic nitrogen, ortho-phosphorus, and organic phosphorus). A constant initial temperature of 16 °C and default constant constituents were specified for the lake along the entire length and depth of the lake. The initial conditions values were based on the calibrated Wolf Lake W2 model, which is in the same vicinity as Dump Lake. The number and location of inflow/outflows are also provided in the control file as part of initial conditions. In addition to the geometric data in the bathymetry file, an initial water surface elevation was specified for the bathymetry of the lake (set equal to the deepest point in the lake).

3.3 Boundary Conditions/Linkages

Boundary conditions are a set of input files required to drive the W2 model. They represent external contributions to the lake. For Dump Lake, inflows were specified at segments 2 and 12 and outflow at segment 9. Apart from the inflows and outflows, four tributaries were configured to account for all the reach inflows from the watershed model flowing into the lake. A distributed tributary load was also applied along the lake to account for the nonpoint source load in the immediate vicinity of the lake (a fraction of this nonpoint source load was used as inflow into Branch 2). Figure B-2 shows the watershed and reach connectivity used in the model. For each of the inflows at Branch 1, Branch 2, and the tributaries, a flow, concentration, and temperature input file was set up.

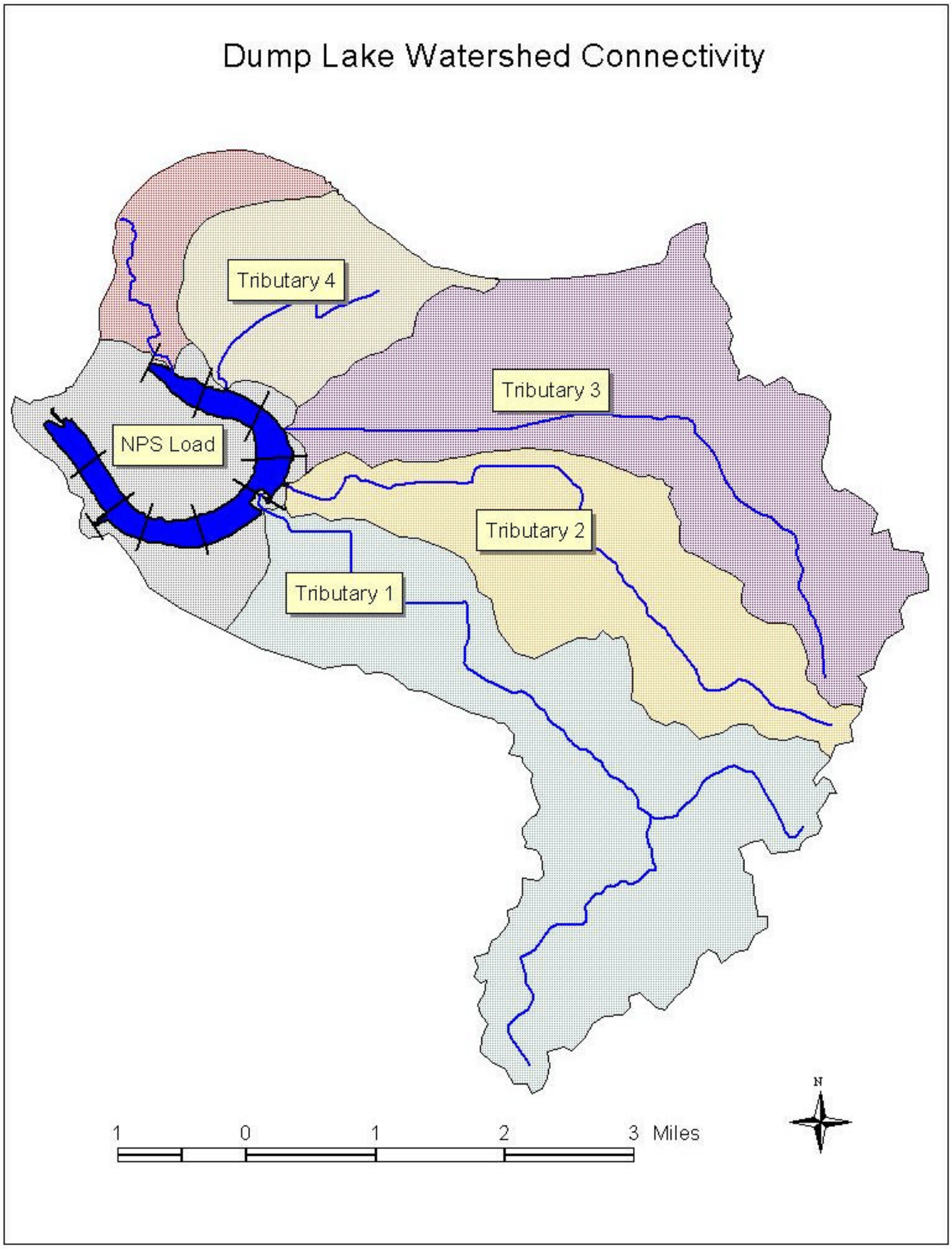

Figure B-2. Dump Lake Watershed Connectivity

The hydrodynamic component of the W2 model, including temperature predictions, was forced by monthly averaged inflows from the GWLF model and hourly surface airways meteorological data. The lake level was assumed to remain constant with the monthly average outflows set equal to inflows.

Temperature time series data corresponding to each inflow for the main branch and tributaries to the lake were required. The watershed model does not simulate temperature and no monitoring data exists for the lake. A generalized temperature time series was created based on the nearby Wolf Lake temperature monitoring data. The observed temperature data followed a sinusoidal pattern along the year for all the monitored temperature stations at Wolf Lake and its inlet. These monitoring data were fitted with a sine curve to obtain a generalized temperature time series that was then used for all simulated years for all inflow boundary conditions in the Dump Lake watershed. The sine function equation is given as

$$T(t) = avgT + Amp \cdot \sin(\Omega \cdot t - f)$$

where:

$avgT$	= average temperature for the time period (t)
Amp	= amplitude
S	= 2B/J
f	= horizontal shift
t	= temperature in degrees Celcius

Parameters in the sine curve equation (amplitude and horizontal phase shift) were adjusted until the line of equal value was reached. Figure B-3 shows the fitted temperature for the temperature data (Wolf Lake inlet data) and the regression of calculated versus observed temperature.

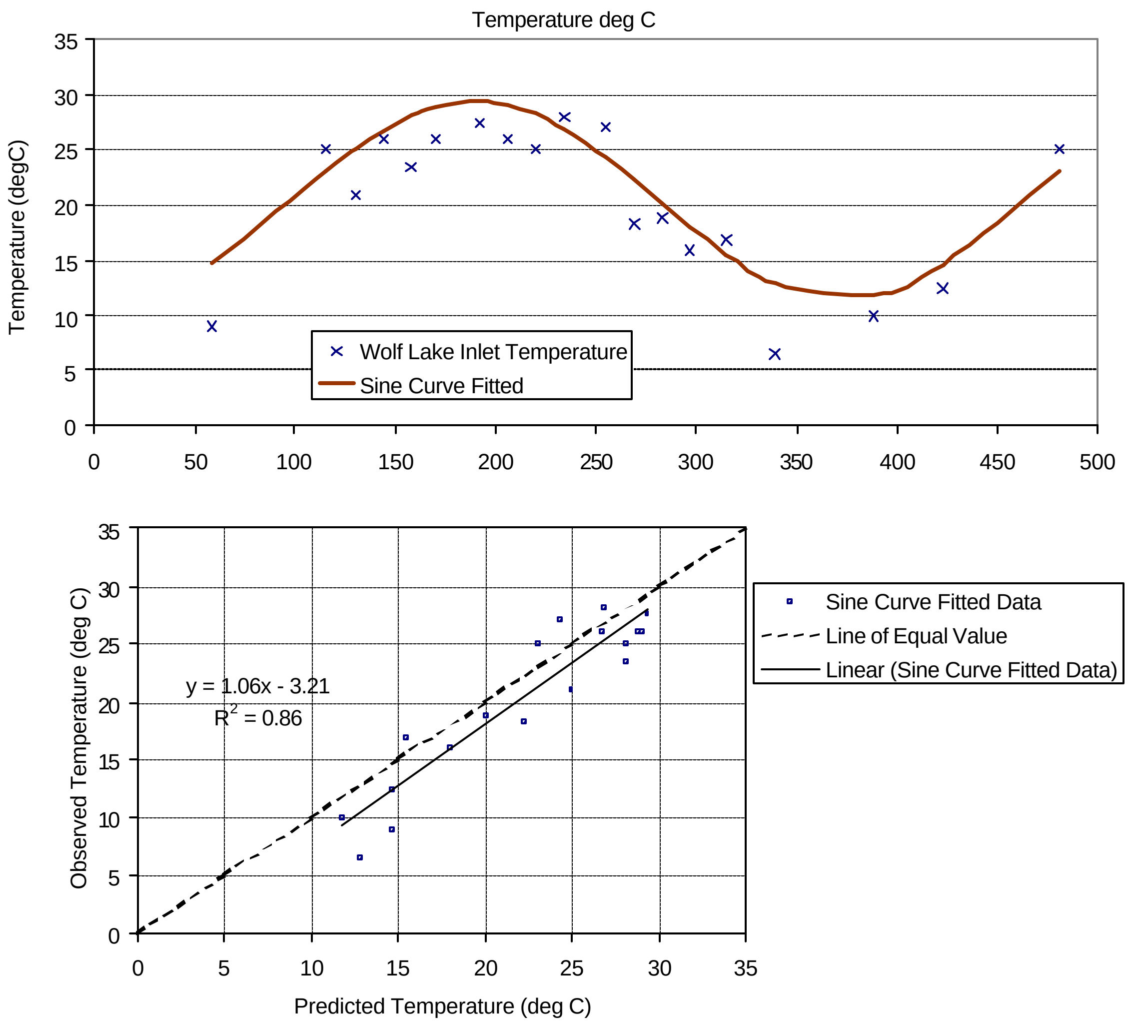

Figure B-3. Sine Curve Fitted Temperature Data using Wolf Lake Inlet Monitoring data.

The water quality component of the W2 model requires loading of dissolved organic material (DOM), particulate organic material (POM), ammonia (NH_3), nitrate-nitrite, ortho-phosphorus (ortho-p) and DO. These loadings were estimated from the total load estimates from the GWLF model. Nutrient ratios as determined from inlake monitoring data for Wolf Lake were used (no monitoring data exits for Dump Lake) to partition total nitrogen (TN) and total phosphorus (TP) into NH_3, nitrate-nitrite, organic nitrogen, ortho-p, and organic phosphorus. Table B-1 shows the time-averaged ratios from the Wolf Lake study that was used. DOM loadings were estimated based on one-half of the organic nitrogen load. POM loadings were estimated from the remaining half of the organic nitrogen and the total organic phosphorus (Tetra Tech, 1997). The DOM and POM form the source of carbon for the model.

Table B-1. Time Averaged Nutrient Ratios (estimated from in-lake data)

Station	NH_3/TN	NOx/TN	Organic N/TN	Ortho-P/TP	Organic P/TP
Average	0.1232	0.1762	0.7006	0.3824	0.6176

The DO was assumed to be entering the lake at 90 percent of saturation. The saturation value was derived from the *Rates Kinetics and Constants Handbook* (USEPA, 1985). A value of 6.67 mg/L of DO was ultimately used.

3.4 Meteorological Data

Meteorological data are an important component of the W2 model. The surface boundary conditions are determined by the meteorological conditions. The meteorological data required by the W2 model are air temperature, dewpoint temperature, wind speed, wind direction, and cloud cover. In general, hourly data are recommended (expressed in Julian Day) (Cole and Buchak, 1995). Hourly meteorological data from the Jackson Airport, which was the nearest available hourly monitoring station and had the most complete dataset, were used (Figure B-4). Short-wave solar radiation was directly calculated in the model. Evaporation is calculated by the model from air temperature, dewpoint temperature, and wind speed.

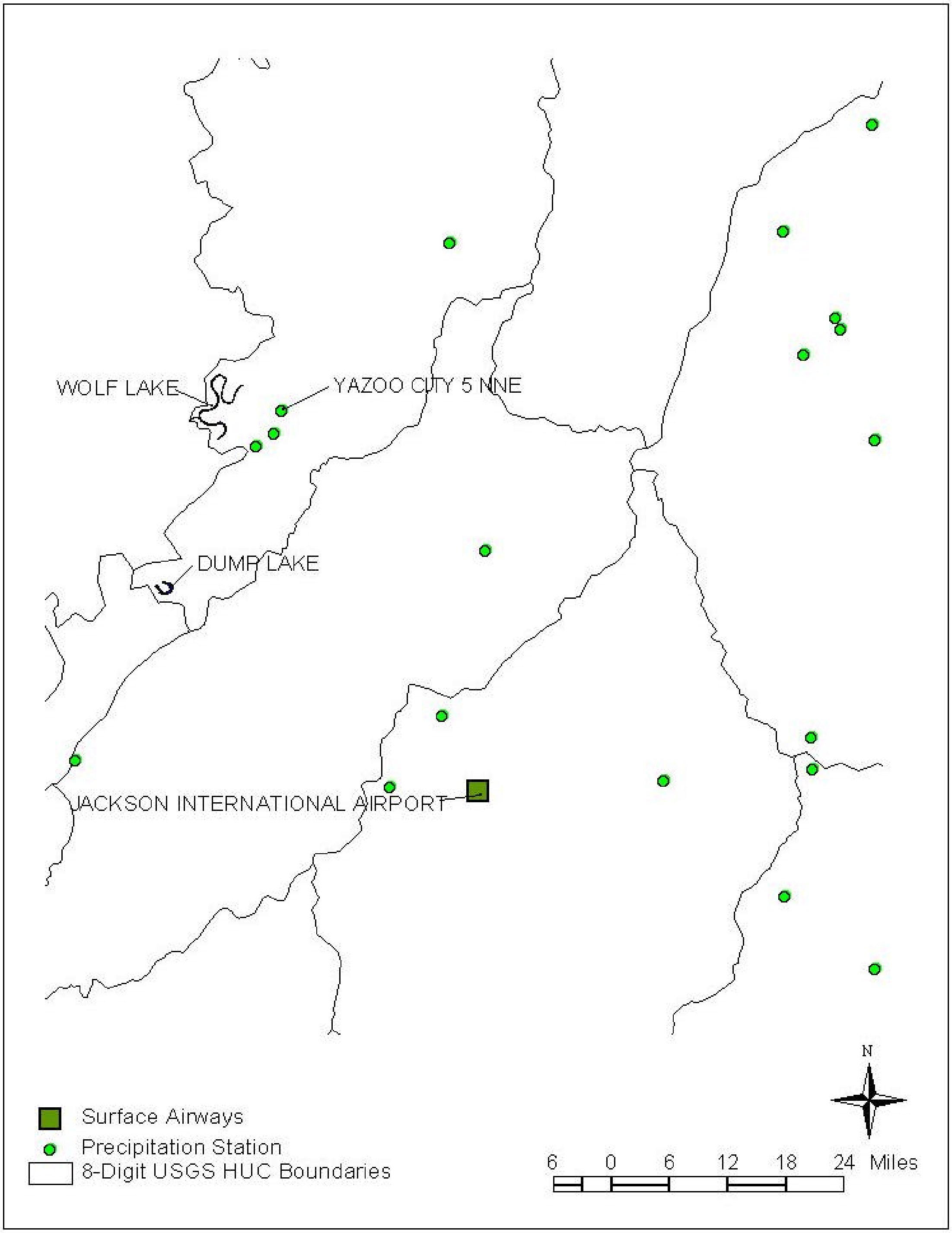

Figure B-4. Weather Station Locations

Recent precipitation data from Yazoo City (Figure B-3) were available but for the lake model evaporation was assumed to cancel out precipitation. Sensitivity on the model runs did not show any major influence of the precipitation falling directly on the lake. However, it may be noted that the effects of precipitation were indirectly considered via the loads coming from the watershed model for which precipitation was the major driver. The GWLF model used the Yazoo City rain gage, which had the most complete, and recent precipitation data (Figure B-4).

For the critical condition period that was chosen (between 1997-2000) hourly climatological data (unedited) exist on the National Oceanographic and Atmospheric Administration National Data Center Web site (from July 1996 onward) for the Jackson Airport meteorological station. Hourly surface airways data were downloaded for each month and a composite file was generated for this period.

3.5 Time Period

No monitoring data is available to support model calibration or validation. The time period chosen for model simulation was from 1997 to 2000. As shown in Figure B-5, 1997-2000 exhibited a wide range of hydrologic conditions with wet and dry periods. Lakes are also typically conducive to eutrophication under these conditions.

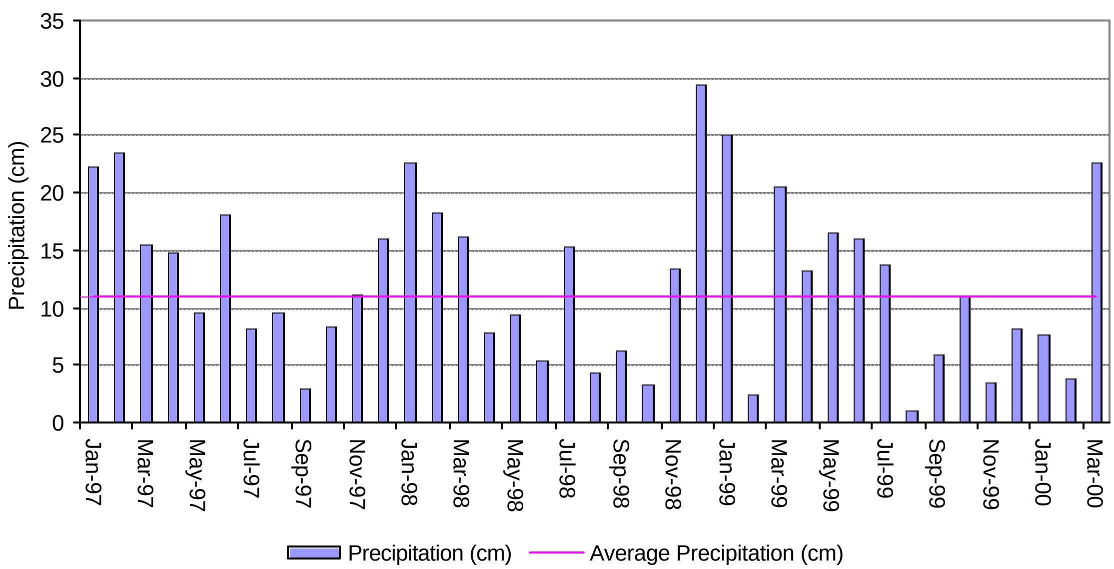

Figure B-5. Monthly Precipitation for period critical period used for simulation 1997-2000 (Yazoo City)

The year 1997 was a predominantly wet year with an annual average of approximately 160 cm, which was 30 cm greater than the mean annual average of 130 cm. 1999 was approximated an average year and 2000 was a relatively dry year with an annual average of 105 cm (Figure B-6). A complete meteorological dataset was available for the years 1997-2000.

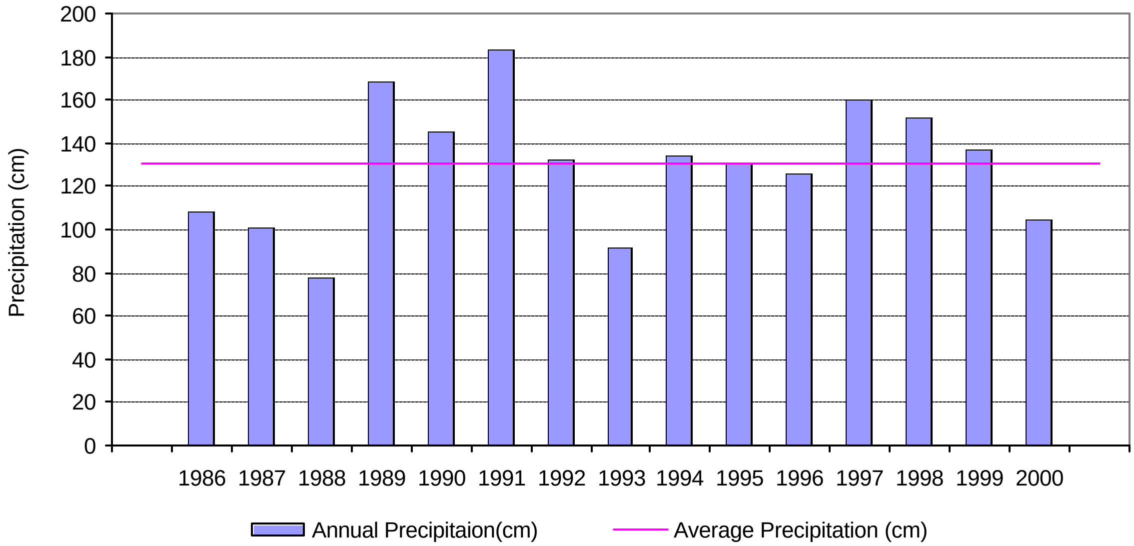

Figure B-6. Monthly Precipitation for 1986 – 2000 (Yazoo City)

4.0 Modeling Parameters

Coefficients are needed to describe the water quality reaction rates in the lake. No monitoring data exist within Dump Lake to calibrate the kinetics. The modeling parameters from the Wolf Lake W2 modeling study were applied to Dump Lake. Since Dump Lake is in the vicinity as that of Wolf Lake, it is assumed that the kinetic parameters of Dump Lake would be similar to that of Wolf Lake. The water quality calibration coefficients as well as the phytoplankton coefficient data (from the Wolf Lake model) used in this study are presented in Table B-2.

Table B-2. Kinetic Coefficients used in the Dump Lake Model

Parameter	Description	Units	Value
PO4R	Sediment release rate of phosphorus	fraction of SOD	0.015
PARTP	Phosphorus partitioning coefficient for suspended solids	-	0.6
NO3DK	Nitrate decay rate	day^{-1}	0.102
NO3T1	Lower temperature for nitrate decay	^oC	0
NO3T2	Upper temperature for nitrate decay	^oC	20
NO3K1	Lower temperature rate multiplier for nitrate decay	-	0.2
NO3K2	Upper temperature rate multiplier for nitrate decay	-	0.99
NH4DK	Ammonium decay rate	day^{-1}	0.30
NH4R	Sediment release rate of ammonium	fraction of SOD	0.05
NH4T1	Lower temperature for ammonium decay	^oC	0
NH4T2	Upper temperature for ammonium decay	^oC	20
NH4K1	Lower temperature rate multiplier for ammonium decay	-	0.2
NH4K2	Upper temperature rate multiplier for ammonium decay	-	0.99
SOD	Sediment oxygen demand	gCm^2day^{-1}	0.5
AG	Growth rate	day^{-1}	2.5
AR	Dark respiration rate	day^{-1}	0.08
AE	Excretion rate	day^{-1}	0.04
AM	Mortality rate	day^{-1}	0.05
AS	Settling rate	day^{-1}	0.1
AHSP	Phosphorus half-saturation coefficient	$g.m^{-3}$	0.003
AHSN	Nitrogen half-saturation coefficient	$g.m^{-3}$	0.014
ASAT	Light saturation	$W.m^{-3}$	100
AT1	Lower temperature for minimum algal rates	^oC	5
AT2	Lower temperature for maximum algal rates	^oC	25
AT3	Upper temperature for minimum algal rates	^oC	30
AT4	Upper temperature for maximum algal rates	^oC	33
AK1	Lower temperature rate multiplier for minimum algal rates	-	0.1
AK2	Lower temperature rate multiplier for maximum algal rates	-	0.85
AK3	Upper temperature rate multiplier for minimum algal rates	-	0.85
AK4	Upper temperature rate multiplier for maximum algal rates	-	0.1

5.0 Assumptions and Limitations

- Kinetic parameters of Wolf Lake were assumed to be applicable to Dump Lake since it was in the same close vicinity.
- Monthly loads are assumed to sufficiently represent loading variability to the lake model.
- The model does not explicitly predict sediment diagenesis processes and long-term effects of reduced nutrient loadings. In order to evaluate the effects of reduced pollutant loading input on DO, SOD rates were reduced accordingly. The SOD rate was reduced by half the percent reduction applied to the nutrients. For example, a 30 percent nutrient load reduction corresponds to a 15 percent SOD rate reduction. This approximate estimate was derived from a lake study which used a predictive sediment diagenesis component (USEPA and RI, 2002)

- The watershed model gives an estimate of the total phosphorus and total nitrogen. These loadings were split based on the nutrient ratios determined from inlake monitoring data of Wolf Lake to provide the required loadings (as per W2 model requirements) of DOM, POM, NH_3, nitrate-nitrite, and ortho-P that feed into the W2 model. Nutrient ratios from Wolf Lake were used since no inlake monitoring exists for Dump Lake to make an estimate of the nutrient ratios.
- No information is available about the low-flow weir at the lake outlet. At present the inflow is set equal to the outflow. Once additional information is made available this can be changed.

6.0 Model Calibration

In general the simulated DO followed a seasonal trend. No model calibration could be performed due to lack of inlake monitoring data. Once monitoring data are made available the model results can be refined and calibration performed. DO simulation results for the years from 1997 to 2000 at segment 6, at mid-depth are shown in Figure B-6.

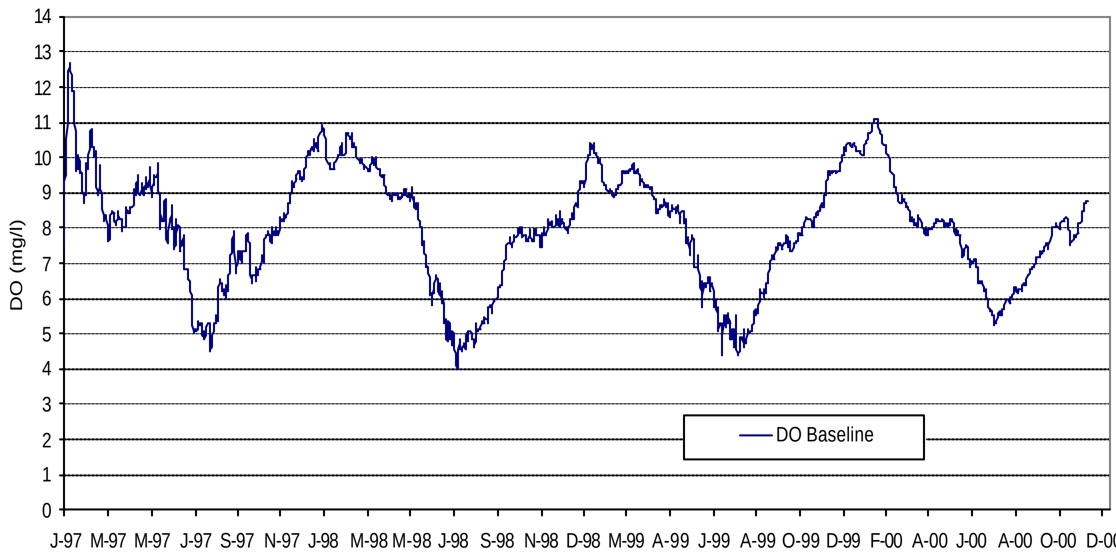

Figure B-6. Baseline DO (1997-2000)

7.0 References

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